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Best Article Award

The ERS Administrator's Award for the Best Article in Agricultural Economics Research for the publication year ending April 1985 went to Douglas Gordon, formerly of the National Economics Division. He was honored at a ceremony on February 12, 1986, for his excellence in creative economic analysis and communication in the article, "Performance of Thin Futures Markets: Rice and Sunflower Seed Futures."

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In This Issue

One of the longer running and still ongoing controversies in economics divides economists into two camps. The first believes in the advantages of the market price system's working in decentralized competitive markets as an instrument for the allocation of resources and the imputation of income. The second is more apt to focus on imperfectly competitive markets and on the flaws in the price system and to see a need for public intervention in the market system. Most observers and participants in the controversy concur that the extreme points—either *laissez-faire* markets or centrally planned and controlled economies—are socially undesirable. Thus, the controversy is really over the proper mix of Government involvement in influencing the market. We have four articles in this issue dealing with different aspects of Government involvement in the agricultural economy.

In the lead article, Salathe and Langley explore alternatives for public intervention in wheat markets. These alternatives include using the executive power of Government to segment domestic and foreign markets and using the spending and taxing power of Government to transfer income to wheat producers, divert land from wheat production, and store grain diverted from the open market. Thus, Salathe and Langley analyze direct Government intervention in income distribution, land use, and supply availability.

The second article, by Hrubovcak, analyzes the effect of Government tax policies on the cost of capital to the farm sector. The type of Government intervention analyzed in this article is a more subtle, yet important, influence on the underlying capital cost structure of agriculture. This influence can affect both the longrun capacity of the sector and the nature of agricultural production.

The third article, by Musser and others, discusses a third role of Government in agriculture. The researchers note that what they believe is a socially preferable production practice is not used by all producers. They report results of a survey of users, past users, and nonusers of the practice and attempt to identify differences in perception of the practice among the three groups. A valid role of Government might be to use these results to design an educational program addressing gaps in information that contribute to the lower level of use of the practice perceived as socially preferable. An interesting finding of the survey was that perception of profitability of the practice differed among groups. The users thought it was profitable to do so. The nonusers did not—a rather normal response to perceived market signals.

In the fourth article, Paarlberg and Webb remind us how recent vulnerability of the farm sector to macroeconomic forces is more nearly the historical norm than was the period in the fifties and sixties, when Government commodity programs and international exchange policies partially insulated the farm sector from these forces.

Just as the continuing controversy in economics on the proper role of Government in a market economy has a long history, so does the study of the role of Government in agriculture. The authors in this issue have contributed to a rich tradition of studies.

Gerald Schluter

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An Empirical Analysis of Alternative Export Subsidy Programs for U.S. Wheat

Larry Salathe and Suchada Langley*

Abstract

U.S. wheat exports have fallen nearly 20 percent since 1981. Major contributing factors appear to be the strong U.S. dollar, debt problems in many grain-importing countries, and mandated support levels providing an umbrella under which U.S. competitors can produce and sell their grains. U.S. subsidies for wheat sales abroad, either directly or by segmenting the domestic and export markets, might offset these factors. This article analyzes the consequences of several export subsidy programs on U.S. producers, consumers, and taxpayers under alternative assumptions regarding the price responsiveness of the world wheat market.

Keywords

Farm programs, international trade, export subsidies, two-price program, wheat

Introduction

U.S. wheat exports have stagnated in recent years. Major contributing factors appear to be a strong dollar and debt problems in many grain-importing countries (*12*).[1] The U.S. wheat loan rate has also kept the U.S. wheat price from falling to market-clearing levels, further reducing the *competitiveness* of U.S. wheat abroad. Some economists argue that the U.S. Government should reduce the cost of U.S. wheat to foreign buyers through direct subsidies or should segment its domestic and export markets using a so-called "two-price" program. This action would reduce the negative effects of relatively high loan rates on U.S. grain exports and still maintain price and income support to farmers. Such programs originally surfaced during the twenties as a way to hold the U.S. price above the world price level, thus enabling farmers to receive a fair market return (*8*). Simply put, export subsidy programs artificially raise the price of grain sold for domestic consumption and lower the price of grain sold to export markets. Thus, domestic grain consumers are taxed whereas foreign consumers receive a subsidy.

Proponents of subsidy programs point out that such programs increase the competitiveness of U.S. grain in international markets, thereby expanding exports and placing additional pressure on the European Community (EC) to reform its agricultural policies. Because the domestic market for U.S. grains is less responsive to changes in market price than is the international market, subsidy proponents also suggest that such programs might be used to increase farmers' net returns and simultaneously reduce Government outlays for price and income support.

However, export subsidy programs have serious negative aspects. As already indicated, these programs increase the price of grain domestically. Consumers pay higher prices for grain-based food products. And, competitor countries would probably view such a program as a major effort by the United States to restrict free trade. Some might retaliate by instituting trade barriers or by increasing export subsidies on either or both agricultural and nonagricultural (such as steel and textile) goods. At a minimum, the United States could lose some of its ability to pressure other countries to reduce trade barriers.

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*Salathe is an agricultural economist with the Economic Analysis Staff, U.S. Department of Agriculture. Langley is an economist with the National Economics Division, ERS. The authors thank Phil Paarlberg, Bob Milton, Jim Zellner, Jim Langley, John Craven, and anonymous reviewers for their helpful comments.

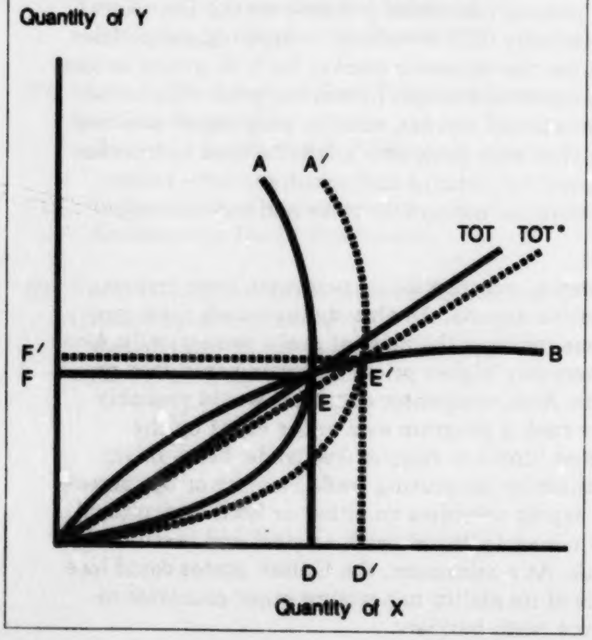
[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

The purpose of this article is to analyze the effects of two alternative export subsidy programs on domestic wheat producers, consumers, and taxpayers. The first alternative is simply a Government export subsidy paid on each bushel of wheat sold for export. The second program would establish a high support price on wheat sold for domestic food use and a much lower support price on wheat sold for export and nonfood domestic uses.

Theoretical Foundations

Assume that the shortrun objectives of an export subsidy program are to raise domestic producer prices and incomes. Let us begin by assuming there are two countries, A and B, and two commodities, X and Y. These assumptions are easily modified without loss of generality. Country A exports X (with domestic and international prices being P_x^d and P_x, respectively) and imports Y (with prices being P_y^d and P_y). Country B imports X and exports Y. Although the pattern of trade could change over time, assume that a fixed pattern holds for the trading world at any point. The figure displays the free-trade and trade subsidy equilibrium.

Trade Equilibrium for Export Subsidies



The curve OA is country A's free-trade offer curve. The shape of the curve is characterized by the increasing opportunity cost of commodity X's production (*1*). OB is country B's free-trade offer curve. Point E, where OA intersects OB, is the free-trade equilibrium. The slope of the straight line, TOT, is the terms of trade in the free-trade world. By providing an export subsidy on commodity X, A's offer curve (subsidy-distorted offer curve) shifts to the right of E. OA′ is the new offer curve for country A under a trade subsidy program. The new equilibrium is E′ where country A is willing to trade OD′ of commodity X for OF′ of commodity Y. TOT*, the new terms of trade, is lower from country A's point of view, but is higher from country B's. Thus, country A has to give up more units of X for each unit of Y than before the subsidy, and the subsidy lowers the world price of X in terms of Y (P_x/P_y). The welfare of country B increases while A's decreases because country A's consumers will pay more for X while country B's consumers will pay less.

The overall results appear contradictory. In terms of domestic welfare, the subsidizing exporter suffers a net welfare loss, although the volume of exports expand. However, the loss in net welfare may decline if the export subsidy is not applied uniformly to all countries (*16*).

In a multicountry world with many importers and exporters, a per-unit subsidy will cause importers to expand their import volume as the subsidy lowers the world price. The subsidizing exporter expands exports at the expense of other exporting countries. The degree to which world prices fall and the export volume of the subsidizing country expands will depend on the level of the subsidy and the responsiveness (elasticities) of demand and supply in importing and exporting countries to changes in world prices, assuming, of course, that other exporters do not retaliate.

Now let us consider more closely the effects of an export subsidy on the U.S. wheat market. For simplicity, assume that there are two markets for U.S. wheat: the domestic market, which we characterize as highly price inelastic, and the export market, which we assume is considerably more responsive to price changes.

If demand in each market is characterized by the following equation:

$$Q_i = a_i - b_i P_i \qquad i = 1,2 \tag{1}$$

where i = 1 is the domestic demand for wheat and i = 2 is the export demand for wheat, then total sector profits (TP) is given by:

$$TP = P_1 Q_1 + P_2 Q_2 - C(Q_1 + Q_2) - FC \tag{2}$$

where C represents variable cost per unit of production and FC represents total fixed costs. Solving equation (1) for P_i and substituting the result into equation (2), one obtains the following expression for total profits:

$$\begin{aligned} TP &= Q_1(a_1 - Q_1)/b_1 \\ &\quad + Q_2(a_2 - Q_2)/b_2 - C(Q_1 + Q_2) - FC \end{aligned} \tag{3}$$

The first-order conditions for profit maximization are:

$$\partial TP/\partial Q_1 = (a_1 - 2Q_1)/b_1 - C = 0 \tag{4}$$

$$\partial TP/\partial Q_2 = (a_2 - 2Q_2)/b_2 - C = 0 \tag{5}$$

Or, equivalently:

$$(a_1 - 2Q_1)/b_1 = (a_2 - 2Q_2)/b_2 \tag{6}$$

Equation (6) states that a monopolist who practices price discrimination will maximize profits by setting the marginal revenue in each market equal to the marginal cost of production. Furthermore, a monopolist selling in more than one market will maximize profits by setting a higher price in the market which exhibits the lower demand elasticity.

Because the domestic wheat market is generally less responsive to price change than the export market, wheat producers' profits would tend to increase if these two markets were segmented with a higher price charged to domestic consumers. Higher returns to producers, in turn, suggest that Government outlays for price and income support might decline, thereby easing the burden on taxpayers. Of course, if a high support price is set on wheat sold domestically, consumers would pay higher prices; however, consumers are also taxpayers. If exports are subsidized directly, farmers' incomes rise and the decline in Government outlays resulting from lower deficiency and diversion payments may offset the cost of the export subsidy.

At what level should domestic and export prices be set? Equation (6) indicates that the marginal revenue in each market should equal marginal cost. For example, variable expenses per bushel for wheat in 1983 averaged $1.41, total domestic use equalled 1.111 billion bushels, and exports totalled 1.429 billion bushels (*18*). The average price received in 1983 was $3.53 per bushel. If we further assume that the own-price elasticity of demand for wheat used domestically is −0.20, then the domestic demand function for wheat can be characterized by the following equation:[2]

$$Q_1 = 1333.21 - 62.95P_1 \tag{7}$$

By substituting the above values for a_1 and b_1 in equation (6), we obtain:

$$\frac{(1333.21 - 2Q_1)}{62.95} = 1.41 \tag{8}$$

$$2Q_1 = 1244.45 \tag{9}$$

$$Q_1 = 622.23 \tag{10}$$

By substituting the value of Q_1 into equation (7) and solving for price, we obtain:

$$622.23 = 1333.21 - 62.95P_1 \tag{11}$$

$$62.95P_1 = 710.98 \tag{12}$$

$$P_1 = 11.29 \tag{13}$$

Thus, a profit-maximizing, price-discriminating monopolist would set the domestic price of wheat at $11.29 per bushel and would market 622 million rather than 1.111 billion bushels domestically.

We can derive corresponding quantities and prices for the export market. Past studies, however, provide a wide range of elasticity estimates for U.S. wheat exports. Rather than selecting one particular value, we steadily increase the export elasticity from 0.25 to 4.00. Table 1 shows the corresponding quantities exported and the export price.

---

[2] Assuming a linear demand function reasonably approximates the true functional relationship between domestic use and price.

Table 1--Price discriminating export quantities and prices

Item	Unit	Export elasticities				
		−0.25	−0.50	−1.00	−2.00	−4.00
Price	Dollars per bushel	9.53	6.00	4.24	3.35	2.91
Quantity	Million bushels	821.80	929.00	1,143.60	1,572.70	2,430.90

The results in table 1 indicate that the export elasticity would have to be approximately 2.00 in the short run before a price-discriminating monopolist would set the export price below $3.53 per bushel, the average farm price for the 1983/1984 crop year. Most past studies indicate that the wheat export elasticity is less than 1.00; thus, a price-discriminating monopolist would set a higher price than $3.53 per bushel in both domestic and export markets (table 2). This situation contrasts with current two-price proposals which involve lowering the support price (below current levels) for wheat for export to increase U.S. competitiveness in world markets.

Theory provides little clue as to whether farmers would be better off if a two-price program included a higher domestic price coupled with a lower export price. We have also ignored losses in transfer payments that could result from stronger domestic prices.

Empirical Model

We used a computer simulation model of the U.S. wheat sector to measure the effects of alternative export subsidy programs for U.S. wheat. The model consists of 39 equations to estimate wheat production, use, price, Commodity Credit Corporation (CCC) loan activity, farmers' gross and net income, consumer expenditures for wheat products, and Government wheat program outlays.

The computer simulation model was developed for use on a personal computer compatible with the Lotus 1-2-3 software. This software solves the simultaneous equation model using policy variables and assumed intercept and slope coefficients as input data for each supply and use function. All functions are linear in parameters, but the flexibility exists to change assumed intercept and slope coefficients each year during the simulation period, thereby allowing the user to analyze alternative policies over a range of various elasticity estimates for supply and use. The default response coefficients in the model stem from past empirical studies of the U.S. wheat sector including previous computer modeling efforts such as FAPSIM (*15*) and WHEATSIM (*10*). We also estimated several functional relationships to update and provide information on response coefficients generally not included in past studies.

Supply

We determined the total supply of wheat by summing production, imports, and beginning stocks. Wheat imports are negligible and treated as exogenous. Beginning stocks equal previous-year ending stocks, and production equals acreage harvested times yield per harvested acre.

We specified acreage harvested as a linear function of acreage planted and yield per harvested acre as a function of acreage planted and acreage set aside and diverted. We assumed acreage planted is related to both market and Government program incentives. Program incentives include target price, loan rate, diversion payment rate, and the proportion of land which must be diverted from production. We also assumed the basis for a farmer's production decision is the return over variable cost of production.

We assumed that the decision to participate in an announced Government acreage reduction program

Table 2—Elasticities of supply and demand for U.S. wheat

Author	Date period	Supply	Food demand	Feed demand	Export demand
			Elasticities		
Blakeslee (*2*)	1954-74	0.047-.188	−0.012	−2.11	−2.00-−3.56
Bredahl, Meyers, Collins (*3*)	NS	—	—	—	0-−1.67
Cochrane, Danin (*4*)	1950-73	—	−.370[1]	—	−.50
Salathe, Price, Gadson (*15*)	1962-79	.290	−.070	−1.49	−.54
Fox (*6*)	1929-53	—	−.067	—	−.50
Gallagher, Lancaster, Bredahl, Ryan (*7*)	1955-75	.510[2]	—	−3.29	−.41
Honma, Heady (*11*)	1968-81	.350	−.200	—	−.44
Longmire, Morey (*12*)	NS	.200	−.400[3]	—	—
Matthews (*13*)	1954-70	—	−.150	—	−.35
Morton, Devados, Heady (*14*)	1960-79	.098	—	−1.73	−.14
Tweeten, Kalbfleisch, Lu (*17*)	NS	—	−.046-−.060	−.56	−.50
Zwart, Meilke (*19*)	1953-74	.090	−.100	—	—

NS = Not specified.
— = Not available.
[1] Total domestic demand.
[2] Winter wheat only.
[3] Total wheat demand.

is determined by the difference in expected returns between participation and nonparticipation. Multiplying the market price for the previous year by the farmer's yield expectation and subtracting variable costs of production provides the estimated expected return from nonparticipation. We estimated yield expectation using a moving average of yields for the previous 5 years excluding the lowest and highest yields. The expected return from participating in an announced acreage reduction program is a function of target price, loan rate, expected market price, expected yield, diversion payment rate, program yield, and the amount of land to be idled (*15*).

Acreage planted is a linear function of the expected program and market returns and acreage set aside and diverted. We hypothesized that an increase in expected market and program returns provides an incentive to plant additional acreage. The model's default coefficients assume that each $10-per-acre increase in expected returns increases planted acreage by 1.5 million acres, implying a price elasticity of 0.22 with respect to acreage. We assume acreage planted would decline by 0.67 of an acre for each 1-acre increase in acreage set aside and diverted, a slippage factor of 0.33 which corresponds to earlier studies (*5, 15*).

Use

The computer simulation model estimates food and industrial use, seed use, feed use, exports, and ending stocks. Ending stocks consist of three components: farmer-owned reserve, CCC stocks, and free stocks. Food and industrial use, exports, and feed use are linear functions of price. Past studies generally indicate that food and industrial use is highly price-inelastic whereas feed use is price-elastic (table 2). However, there is little consensus about the responsiveness of U.S. wheat exports to changes in price. The default slope coefficients in the model assume elasticities (based on 1984 crop year estimates) of −0.07, −1.05, and −0.45 for food and industrial use, feed use, and exports, respectively.

We patterned the functional relationships for farmer-owned reserves, CCC stocks, and free stocks after those in FAPSIM (*15*). Free stocks are a function of price and the level of farmer-owned reserve stocks. The model assumes that each 1-bushel increase in reserve stocks would reduce free stocks by 0.3 bushel.

We assumed that wheat placed in the farmer-owned reserve would remain in the reserve for 5 years unless market price equals or exceeds the reserve release price. If price fails to reach the release level during the 5-year period, reserve placements would default to the CCC. If price exceeds the release price during the contract period or the loan rate plus interest charges at the end of the contract period, reserve stocks become available to the open market.

CCC stocks consist of stocks acquired by the Government through price-support programs. We assumed that CCC stocks would accumulate as farmers default on reserve and regular CCC loans. CCC stocks are available to the open market only when the market price exceeds the reserve release price by 5 percent.

Loan Activity

The model predicts price-support loan activity based on market price, loan rate, and CCC interest charges. The loan activity component of the model consists of five equations. The first, beginning outstanding loans, equals the sum of outstanding reserve and regular CCC loans at the beginning of the crop year. Loan placements are based on an econometric relationship and are a function of the market price and the loan rate. If price is between the CCC loan rate and the release price, each 10-percent increase in the market price relative to the loan rate reduces total loan placements by 76 million bushels.

Total loan repayments consist of reserve loan and regular 9-month loan repayments. We assumed that farmers will repay outstanding loans at the beginning of the crop year if price exceeds the loan rate plus interest charges. If price fails to exceed the loan rate plus interest charges, outstanding loans would default to the CCC. We then added the quantity of grain defaulted to the CCC to existing CCC stocks.

Market Price

We determined the market price of wheat by solving the supply-demand equilibrium condition for price. For example, total supply is predetermined at the beginning of the crop year. The equilibrium price is that price which equates total supply and total use plus ending stocks. Because all use equations and ending stocks are linear in price, we can solve these equations to determine that price which uniquely equates supply and demand.[3]

Market price can be altered by Government reserve and CCC stock programs. For example, the reserve may act to hold prices at the release level when supply is low relative to demand. To account for such policies, we used decision rules to adjust market prices in situations when price is estimated to exceed the release level or to fall below the loan rate. First, we assumed that the 9-month regular loan generally acts as a price floor and the minimum market price thus becomes the loan rate. Second, as mentioned earlier, we assumed that reserve and CCC stocks would be placed back on the open market when prices reach their corresponding release levels. Under this situation, the market price equals the release price, and the market price does not exceed the release price unless total reserve or CCC stocks are depleted.

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[3] Under the $7.00 (domestic price)/$2.50 (export price) and $10.00/$2.50 two-price programs analyzed in this study, we calculated the equilibrium market price by first estimating the level of food and industrial use, by subtracting that figure from the total available supply, and by then determining that price which uniquely equates the reduced available supply and total demand less food and industrial use.

Income Indicators

The model estimates the change in farmers' net income resulting from a change in Government policy. The model estimates farmers' gross income by summing the value of production (price times production), deficiency payments, diversion payments, and reserve storage payments. We calculated deficiency payments by multiplying the difference between the target price and the maximum of the loan rate and the 5-month market price by the participation rate, program yield, base acreage, and 1 minus the set-aside and diversion rate. We estimated diversion payments by multiplying the diversion payment rate by the program yield, base acreage, and proportion of land diverted from production. We determined storage payments by multiplying the level of reserve stocks by the reserve storage payment rate per bushel. Farmers' net income is calculated as gross income minus variable production expenses per planted acre times planted acreage.

Net CCC Outlays

We estimated CCC loan outlays by subtracting the basis. We derived these estimates by allocating crop-year loan activity and Government payments between fiscal years. The model endogenously estimates both Government payments and changes in CCC loan activity. Government payments consist of deficiency, diversion, and reserve storage payments. We estimated CCC loan outlays by subtracting the value of loan placements (loan placements times the current loan rate) from the value of loan repayments. An additional cost to the Government is the cost of storing and handling existing CCC stocks. We calculated this outlay by multiplying the average CCC stock level by a fixed cost per bushel for storage and handling.

Consumer Expenditures

We estimated consumer expenditures for bakery products by multiplying the farm price by the quantity of wheat used for food and industrial use plus marketing, processing, and transportation costs.[4] We assumed that costs beyond the farm gate would increase at about the rate of inflation during the study period and would remain unaffected by changes in wheat export programs.

Baseline Assumptions

We simulated each export program over the crop year period from 1985/86 through 1991/92. Thus, the simulated impacts are conditional upon assumptions regarding demand growth, productivity, and agricultural policies and programs.

Current agricultural legislation expired in 1985. Rather than attempt to out-guess the Congress, we assumed future legislation would not be radically different from current farm policies and programs. That is, the Secretary of Agriculture would still have the authority to implement acreage reduction and land diversion programs if needed. We assumed that target prices and loan rates would be mandated at minimum levels of $4.38 and $3.30 per bushel, respectively, for 1986/87 through 1991/92, the same as in 1984/85 and 1985/86. We assumed that the diversion payment rate and farmer-owned reserve storage payment rate would remain at $2.70 and $0.265 per bushel throughout the simulation period.

We assumed that productivity would continue to grow at the pace of the past decade. Wheat yields per harvested acre are forecast to increase by about 0.6 bushel per acre per year. Food and industrial use should increase with population growth, rising from about 650 million bushels in 1985/86 to about 700 million bushels in 1991/92. Seed use should remain at about 90 million bushels throughout the simulation period, reflecting the expectation of minimal growth in wheat acreage from 1985/86 through 1991/92. Feed use will average about 255 million bushels over the period, declining from 1984/85 levels as the price of corn declines from its drought-heightened 1983 level to a more normal relationship with wheat. Wheat export growth will likely be considerably below that of the seventies.

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[4] Under the $7.00/$2.50 and $10.00/$2.50 program alternatives, we substituted the domestic support price for food and industrial use for the farm price when calculating consumer expenditures for bakery products.

We expect wheat exports will remain steady at about 1.3 billion bushels for 1985/86 through 1987/88 and then steadily rise to slightly over 1.4 billion bushels for 1991/92. This forecast assumed that the dollar will remain strong in world markets with slow economic growth and a continuation of debt-financing problems in many less-developed countries. We also assumed the United States will continue current export credit guarantee and export promotion programs at about the same funding level as in fiscal year 1984.

Given these assumptions, an initial simulation indicated that ending stocks would remain large in relation to historical levels and that wheat prices would remain depressed throughout the 1985/86 to 1991/92 period in the absence of a land retirement or an expanded export program. We, therefore, assumed the Secretary will announce an acreage reduction program to cut supplies, strengthen prices, and reduce CCC program outlays. Under the baseline, the 20-percent acreage reduction and 10-percent paid land diversion program announced for 1985 is continued through 1991/92. This program removes about 20 million acres from production each year. Despite the placement of about 20 million acres in conserving use each year, ending wheat stocks grow from about 1.5 billion bushels in 1985/86 to over 3 billion bushels by the end of the 1991/92 marketing year. The average farm price of wheat increases moderately under the baseline policy scenario from $3.30 per bushel in 1985/86 to about $3.37 per bushel in 1991/92. CCC net outlays under the baseline average over $4.2 billion per year with over half the outlays being in the form of deficiency and diversion payments.[5]

Empirical Analysis

We analyzed two types of export subsidy programs. Because of the wide range of elasticity estimates for U.S. wheat exports, we ran each program with the export elasticity ranging from −0.25 to −4.00. We chose this range to provide information on the likely effects of each program alternative and on the sensitivity of the estimates to the choice of the export elasticity.

We conducted a total of five simulations. The first simulation assumes a direct subsidy of 50 cents per bushel on each bushel of wheat for export, and the second assumes a direct subsidy of $1 per bushel. The third assumes a direct subsidy of $1.50 per bushel coupled with elimination of production controls. The final two simulations also assume elimination of production controls with the Government's setting a $7 and $10 per bushel support price for wheat for domestic food and industrial use, respectively. In these final two simulations, we set the support price for wheat for export and other domestic uses at $2.50 per bushel; the program would be financed by taxing wheat processors.

Export Subsidy of 50 Cents per Bushel

The simulation results indicate that compared with the baseline, a 50-cent-per-bushel subsidy on each bushel of wheat for export would increase U.S. wheat exports, farm prices, and wheat production.[6] Assuming wheat exports have an elasticity of 0.5, farm price would increase by 10 cents per bushel on average for crop years 1985/86 to 1991/92 (table 3). Harvested acreage would increase on average by less than 1 million acres, production by about 20 million bushels, and exports by about 85 million bushels. Ending stocks would average about 215 million bushels lower over the simulation period. Compared with the baseline, farmers' gross income would average about $80 million higher, CCC net outlays about $240 million higher, and consumer expenditures about $65 million higher.

A closer examination of the results in table 3 reveals that, as the export elasticity increases, farm price and farmers' incomes rise, CCC net outlays fall, and consumer expenditures increase. A 50-cent-per-bushel export subsidy would increase farmers' incomes even when the export elasticity is assumed to be below 1, because higher farm prices more than offset the decline in income resulting from lower deficiency payments.

Although farmers' gross and net incomes would be higher, CCC net outlays would not fall below their

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[5] This baseline is used only for comparison and does not represent official USDA estimates.

[6] For over 50 years, U.S. wheat export subsidies ranging from 1 to 95 cents per bushel were paid to grain export companies. Subsidy payments ended in September 1972 when the U.S. price came into line with the world market price (*9*).

Table 3—Effects of an export subsidy of 50 cents per bushel[1]

Item	Unit	Baseline	Export elasticities				
			−0.25	−0.50	−1.00	−2.00	−4.00
Acreage planted	Million acres	72.52	72.96	73.33	73.74	74.05	74.53
Acreage harvested	do.	65.27	65.66	66.00	66.37	66.65	67.09
Yield per acre	Bushels	41.00	40.91	40.84	40.77	40.71	40.63
Supply:	Million bushels						
Beginning stocks	do.	2,183.07	2,085.62	2,019.77	1,914.82	1,680.12	1,276.60
Production	do.	2,674.25	2,685.67	2,695.16	2,705.43	2,712.99	2,725.39
Imports	do.	3.00	3.00	3.00	3.00	3.00	3.00
Total	do.	4,860.32	4,774.29	4,717.93	4,623.25	4,396.11	4,004.99
Use:							
Food and industry	do.	678.99	678.26	677.74	676.89	676.40	675.52
Seed	do.	91.21	91.74	92.20	92.71	93.08	93.67
Feed	do.	254.80	248.52	243.96	236.61	232.38	224.81
Exports	do.	1,382.14	1,427.86	1,464.83	1,519.29	1,624.25	1,749.39
Total	do.	2,407.15	2,446.39	2,478.74	2,525.49	2,626.11	2,743.39
Ending stocks	do.	2,453.18	2,327.19	2,239.19	2,097.96	1,770.00	1,261.59
Price	Dollars per bushel	3.33	3.39	3.43	3.50	3.54	3.61
Income indicators:	Million dollars						
Value of production	do.	8,909.74	9,105.01	9,249.30	9,468.60	9,600.20	9,837.87
Deficiency payments	do.	1,920.07	1,799.29	1,702.80	1,565.55	1,477.47	1,324.47
Storage payments	do.	152.41	145.32	141.14	136.09	130.89	124.29
Diversion payments	do.	789.26	772.08	757.39	741.44	729.47	710.60
Total gross income	do.	11,771.47	11,821.70	11,850.62	11,911.67	11,938.03	11,997.23
Variable expenses	do.	4,485.36	4,512.57	4,535.46	4,560.82	4,579.99	4,609.68
Total net income	do.	7,286.11	7,309.12	7,315.16	7,350.85	7,358.04	7,387.55
Net CCC outlays:[2]							
Deficiency payments	do.	1,770.90	1,657.17	1,556.50	1,450.01	1,356.59	1,225.60
Diversion payments	do.	791.69	773.94	759.59	740.94	727.22	708.82
Storage payments	do.	150.33	143.21	139.03	134.49	129.09	123.13
Net lending	do.	931.41	829.26	748.69	609.87	290.67	−61.22
Export subsidy	do.	0	712.18	729.95	758.37	809.88	873.08
Other	do.	558.37	530.81	509.83	472.16	370.44	190.49
Total	do.	4,202.69	4,646.57	4,443.60	4,165.84	3,683.90	3,059.89
Consumer expenditures[3]	do.	37,783.45	37,821.71	37,847.06	37,891.53	37,916.87	37,961.04

[1] Unless indicated otherwise, numbers are crop year 1985/86 to 1991/92 averages.
[2] Fiscal year 1986-91 averages.
[3] For bakery products.

baseline value unless the export elasticity is nearly 1. Thus, the export elasticity must be nearly 1 before the cost of the export subsidy would be more than offset by Government savings from lower deficiency, storage, and diversion payments and from lower CCC net loan activity and storage costs. If the cost of supporting farmers' incomes is calculated as the change in CCC net outlays and consumer expenditures, the export elasticity must be above 1 before the total cost of supporting farm income would fall below its baseline value.

The simulation results suggest that farmers' incomes, CCC net outlays, and consumer expenditures do not vary greatly from their baseline values despite the wide range for the export elasticity. Assuming an export elasticity of 2, farmers' gross income less variable expenses would average less than 1 percent higher ($72 million), CCC net outlays less than 13 percent lower ($519 million), and consumer expenditures less than 1 percent ($133 million) higher than their respective baseline values.

Earlier we stated that economic theory indicates that the subsidizing exporter suffers a net welfare loss. The results, however, suggest that, for some values of the export elasticity, an export subsidy could result in net benefits to society as taxpayer savings plus increases in farmers' incomes exceed increases in consumer costs. At first glance, the results appear inconsistent with economic theory. However, economic theory generally begins with the assumption of perfect competition or no Government intervention and then measures the effects of a change in policy on consumers, taxpayers, and producers. But, the baseline from which the effects of each program are measured assumes that the Government will intervene in the wheat market by implementing acreage reduction and paid land diversion programs and by providing income and price protection to producers by setting target prices and loan rates. This basic difference in the policy environment from which the export subsidy effects are measured explains why our results differ from those generated under the assumption of perfect competition or no Government intervention.

Export Subsidy of $1 per Bushel

Assuming a subsidy of $1 per bushel rather than 50 cents will increase wheat farmers' gross income at each value of the export elasticity (table 4). If the export elasticity equals 0.5, a $1-dollar-per-bushel export subsidy would increase wheat exports on average by nearly 170 million bushels, the price of wheat by 18 cents per bushel, and wheat farmers' gross income less variable expenses by nearly $68 million. Compared with the baseline, CCC net outlays average $594 million per year higher and consumer expenditures increase by nearly $115 million per year if the export elasticity equals 0.5.

Again, CCC net outlays fail to decline below their baseline value unless the export elasticity is nearly 1. However, if the total cost of supporting farmers' incomes is calculated as the change in both CCC net outlays and consumer expenditures, the total cost of supporting farmers' incomes would exceed its baseline value unless the export elasticity is above 1. Assuming an export elasticity of 4, farmers' net income would average $397 million per year higher (or about 5.4 percent above its baseline value), CCC net outlays about $1,140 million lower (27.1 percent), and consumer expenditures for bakery products about $434 million higher (1.1 percent).

Export Subsidy of $1.50 per Bushel and No Production Controls

In an attempt to reduce CCC net outlays, one alternative is to eliminate production controls and thereby to eliminate deficiency and diversion payments. In fact, some analysts argue that production controls reduce U.S. competitiveness in world markets as competitor countries expand production while the United States simultaneously idles land. A policy of no production controls coupled with a direct subsidy on exports would provide a signal that the United States is unwilling to balance world supply and demand for wheat by adjusting production.

If one assumes an export elasticity of 0.5, the farm price would average 14 cents per bushel higher and acreage harvested would average about 11 million acres higher than under a continuation of current programs (table 5). Wheat production would increase on average by about 200 million bushels, and the export subsidy of $1.50 per bushel would increase exports by nearly 283 million bushels despite the higher price for wheat. But, wheat farmers' gross income would average over $1.6 billion lower

Table 4—Effects of an export subsidy of $1 per bushel[1]

Item	Unit	Baseline	Export elasticities				
			−0.25	−0.50	−1.00	−2.00	−4.00
Acreage planted	Million acres	72.52	73.34	73.84	74.30	75.89	77.41
Acreage harvested	do.	65.27	66.00	66.46	66.88	68.32	69.71
Yield per acre	Bushels	41.00	40.84	40.75	40.67	40.38	40.10
Supply:	Million bushels						
Beginning stocks	do.	2,183.07	1,988.62	1,831.26	1,445.60	1,218.31	1,149.23
Production	do.	2,674.25	2,695.23	2,707.79	2,719.66	2,759.04	2,795.72
Imports	do.	3.00	3.00	3.00	3.00	3.00	3.00
Total	do.	4,860.32	4,686.86	4,542.05	4,168.26	3,980.35	3,947.94
Use:							
Food and industry	do.	678.99	677.72	676.72	676.00	673.12	670.41
Seed	do.	91.21	92.20	92.82	93.39	95.34	97.22
Feed	do.	254.80	243.77	235.17	228.97	204.06	180.67
Exports	do.	1,382.14	1,475.17	1,551.70	1,697.51	1,821.20	1,900.87
Total	do.	2,407.15	2,488.86	2,556.41	2,695.88	2,793.72	2,849.17
Ending stocks	do.	2,453.18	2,197.99	1,985.64	1,472.39	1,186.64	1,098.77
Price	Dollars per bushel	3.33	3.43	3.51	3.57	3.80	4.02
Income indicators:	Million dollars						
Value of production	do.	8,909.74	9,254.52	9,512.55	9,711.22	10,489.61	11,234.00
Deficiency payments	do.	1,920.07	1,699.96	1,535.36	1,404.65	937.32	557.48
Storage payments	do.	152.41	141.63	135.59	127.43	105.52	82.77
Diversion payments	do.	789.26	757.31	737.72	719.42	656.87	596.39
Total gross income	do.	11,771.47	11,853.42	11,921.01	11,962.72	12,189.17	12,470.63
Variable expenses	do.	4,485.36	4,536.08	4,567.00	4,595.46	4,693.80	4,787.81
Total net income	do.	7,286.11	7,317.34	7,354.01	7,367.27	7,495.37	7,682.82
Net CCC outlays:[2]							
Deficiency payments	do.	1,770.90	1,558.87	1,423.08	1,289.15	871.61	518.19
Diversion payments	do.	791.69	759.51	736.60	718.42	652.11	586.85
Storage payments	do.	150.33	139.86	133.83	125.94	104.89	82.87
Net lending	do.	931.41	712.46	519.61	65.74	−134.37	−217.50
Export subsidy	do.	0	1,471.33	1,549.07	1,692.17	1,819.39	1,901.85
Other	do.	558.37	494.95	434.48	265.34	190.49	190.49
Total	do.	4,202.69	5,136.78	4,796.69	4,156.76	3,504.12	3,063.75
Consumer expenditures[3]	do.	37,783.45	37,847.03	37,897.74	37,935.77	38,080.31	38,217.50

[1] Unless indicated otherwise, numbers are crop year 1985/86 to 1991/92 averages.
[2] Fiscal year 1986-91 averages.
[3] For bakery products.

Table 5—Effects of no production control programs and an export subsidy of $1.50 per bushel[1]

Item	Unit	Baseline	Export elasticities				
			−0.25	−0.50	−1.00	−2.00	−4.00
Acreage planted	Million acres	72.52	84.14	84.77	85.38	87.35	88.88
Acreage harvested	do.	65.27	75.81	76.39	76.94	78.73	80.12
Yield per acre	Bushels	41.00	37.70	37.67	37.64	37.55	37.48
Supply:	Million bushels						
Beginning stocks	do.	2,183.07	2,222.74	1,939.34	1,325.02	1,148.59	1,000.12
Production	do.	2,674.25	2,856.97	2,876.49	2,895.59	2,956.29	3,003.28
Imports	do.	3.00	3.00	3.00	3.00	3.00	3.00
Total	do.	4,860.32	5,082.70	4,818.82	4,223.61	4,107.88	4,006.40
Use:							
Food and industry	do.	678.99	678.95	677.29	675.65	670.33	666.21
Seed	do.	91.21	105.49	106.27	107.02	109.44	111.32
Feed	do.	254.80	254.42	240.06	225.97	179.95	144.35
Exports	do.	1,382.14	1,537.30	1,664.83	1,893.33	2,050.69	2,172.59
Total	do.	2,407.15	2,576.16	2,688.45	2,901.98	3,010.61	3,094.48
Ending stocks	do.	2,453.18	2,506.55	2,130.38	1,321.63	1,097.27	911.82
Price	Dollars per bushel	3.33	3.33	3.47	3.60	4.02	4.35
Income indicators:	Million dollars						
Value of production	do.	8,909.74	9,528.81	9,975.60	10,421.99	11,899.56	13,078.15
Deficiency payments	do.	1,920.07	0	0	0	0	0
Storage payments	do.	152.41	152.03	138.90	125.37	82.53	52.53
Diversion payments	do.	789.26	0	0	0	0	0
Total gross income	do.	11,771.47	9,680.84	10,114.50	10,547.36	11,982.08	13,130.68
Variable expenses	do.	4,485.36	5,204.06	5,243.02	5,280.75	5,402.60	5,497.23
Total net income	do.	7,286.11	4,476.78	4,871.48	5,266.61	6,579.48	7,633.45
Net CCC outlays:[2]							
Deficiency payments	do.	1,770.90	0	0	0	0	0
Diversion payments	do.	791.69	0	0	0	0	0
Storage payments	do.	150.33	149.99	137.08	124.31	82.74	51.88
Net lending	do.	931.41	977.10	641.40	−40.28	−220.65	−374.96
Export subsidy	do.	0	2,300.90	2,491.79	2,833.05	3,075.14	3,266.52
Other	do.	558.37	579.41	478.76	211.45	190.49	167.12
Total	do.	4,202.69	4,007.40	3,749.03	3,128.50	3,127.73	3,111.56
Consumer expenditures[3]	do.	37,783.45	37,783.32	37,872.61	37,954.75	38,217.14	38,420.43

[1] Unless indicated otherwise, numbers are crop year 1985/86 to 1991/92 averages.

[2] Fiscal year 1986-91 averages.

[3] For bakery products.

than under the baseline as higher prices and increased production would fail to offset the loss in income from eliminating deficiency and diversion payments. Farmers' net income would fall by over $2.4 billion per year as production costs would rise because of expanded acreage. CCC net outlays would decline far less ($454 million) than would farmers' income, and consumer expenditures would average about $89 million higher.

Farmers' net income would fail to average above the level under current programs unless the export elasticity were to exceed 3.5. Farmers' gross income less variable costs would average 9.7 percent below its baseline value if the export elasticity were 2 and would exceed its baseline value by 4.8 percent if the export elasticity were 4.

Eliminating deficiency and diversion payments would reduce CCC net outlays even though exports are subsidized at $1.50 per bushel. CCC net outlays would average about $200 million to nearly $1.1 billion lower, but would fail to average less than $3 billion per year even if the export elasticity were 4.

Compared with the baseline, consumer expenditures would increase even though production controls would be eliminated because the export subsidy of $1.50 per bushel would increase the price of wheat domestically. Consumer expenditures would average $637 million higher if the export elasticity were 4. Total support costs including the change in consumer expenditures would decline by $454 million if the export elasticity were 4 and by $195 million if the export elasticity were 0.25.

$7/$2.50 Two-Price Program

Under this two-price program, wheat for domestic food and industrial use would be supported at $7 per bushel, whereas wheat for export, feed, and other nonfood uses would be supported at $2.50 per bushel. Wheat for food and industrial use would be supported through direct payments to producers and financed by a tax on wheat processors. Wheat processors would pass the cost of the tax on to consumers through higher prices for processed wheat products. We also assumed that all production control programs would be eliminated and that producer production response would be determined by the level of farm prices and would, therefore, be independent of the support level for wheat for food and industrial use.

The lack of production controls combined with lower food and industrial use, resulting from the $7-per-bushel support price, would cause the average farm price to fall below its baseline value. Food and industrial use would average about 45 million bushels lower, and wheat production would average 74-144 million bushels higher compared with a continuation of current farm programs (table 6). The farm price of wheat would fall by 25-73 cents per bushel depending on the magnitude of the export elasticity. Compared with their respective baseline values, exports would average 76-422 million bushels higher and ending stocks would average 133-1,011 million bushels lower.

The simulation results indicate farmers' net income would fall despite the $7-per-bushel support price on wheat for food and industrial use. Support payments to producers tend to greatly offset the effects of eliminating deficiency and diversion payments, but lower prices and expanded acreage cause farmers' net income to decline below its baseline value unless the export elasticity is substantially above 4. If the export elasticity were 0.5, farmers' net income would fall below its baseline value by over $2 billion per year and, if the export elasticity were 1, income would average over $1.9 billion per year lower.

CCC net outlays would decline dramatically under this program option. With the elimination of CCC-financed deficiency payments and no diversion payments, CCC outlays would be limited to loan activity, reserve storage payments, and costs of storing and handling CCC-owned wheat. CCC net outlays would average from $1.2 billion to less than $300 million per year or about $3 billion to nearly $4 billion lower than under a continuation of current farm programs.

The costs of supporting farmers' income is reflected in higher consumer expenditures for wheat products. Compared with the baseline, consumer expenditures for bakery products would average nearly $2.2

Table 6—Effects of a $7/$2.50 two-price program[1]

Item	Unit	Baseline	Export elasticities				
			−0.25	−0.50	−1.00	−2.00	−4.00
Acreage planted	Million acres	72.52	80.66	80.91	81.30	82.08	82.90
Acreage harvested	do.	65.27	72.66	72.88	73.23	73.94	74.69
Yield per acre	Bushels	41.00	37.86	37.85	37.83	37.80	37.76
Supply:	Million bushels						
Beginning stocks	do.	2,183.07	2,095.39	1,954.74	1,737.91	1,516.07	1,444.86
Production	do.	2,674.25	2,748.48	2,755.92	2,768.02	2,792.51	2,818.37
Imports	do.	3.00	3.00	3.00	3.00	3.00	3.00
Total	do.	4,860.32	4,846.87	4,713.71	4,508.93	4,311.58	4,266.22
Use:							
Food and industry	do.	678.99	633.13	633.13	633.13	633.13	633.13
Seed	do.	91.21	101.22	101.52	102.00	102.95	103.97
Feed	do.	254.80	334.13	328.07	320.38	310.47	282.36
Exports	do.	1,382.14	1,458.23	1,522.69	1,633.94	1,740.08	1,804.29
Total	do.	2,407.15	2,526.70	2,585.40	2,689.44	2,277.63	2,823.75
Ending stocks	do.	2,453.18	2,320.17	2,128.31	1,819.50	1,533.95	1,442.48
Price	Dollars per bushel	3.33	2.60	2.65	2.72	2.90	3.08
Income indicators:	Million dollars						
Value of production	do.	8,909.74	7,137.36	7,311.74	7,539.17	8,096.20	8,669.70
Deficiency payments	do.	1,920.07	2,787.44	2,752.14	2,707.76	2,596.38	2,484.24
Storage payments	do.	152.41	141.00	136.40	128.09	106.80	80.88
Diversion payments	do.	789.26	0	0	0	0	0
Total gross income	do.	11,771.47	10,065.80	10,200.80	10,375.03	10,799.38	11,234.82
Variable expenses	do.	4,485.36	4,988.82	5,004.28	5,028.41	5,076.65	5,121.18
Total net income	do.	7,286.11	5,076.98	5,196.00	5,346.62	5,722.73	6,113.64
[illegible] CCC outlays:[2]							
Deficiency payments	do.	1,770.90	0	0	0	0	0
Diversion payments	do.	791.69	0	0	0	0	0
Storage payments	do.	150.33	139.00	134.77	126.51	106.53	81.24
Net lending	do.	931.41	529.06	394.38	151.79	−54.65	−127.36
Export subsidy	do.	0	0	0	0	0	0
Other	do.	558.37	499.09	446.03	357.03	280.21	280.22
Total	do.	4,202.69	1,167.15	975.17	635.34	332.11	234.10
Consumer expenditures[3]	do.	37,783.45	39,954.32	39,954.32	39,954.32	39,954.32	39,954.32

[1] Unless indicated otherwise, numbers are crop year 1985/86 to 1991/92 averages.
[2] Fiscal year 1986-91 averages.
[3] For bakery products.

billion per year higher. Over the entire range of export elasticities, the cost of supporting farmers' income by consumers and taxpayers would average about $850 million to $1.8 billion per year lower than under current programs. Farmers' net income would average about $2.2 billion to $1.2 billion lower over the range of export elasticities.

$10/$2.50 Two-Price Program

Under the $7/$2.50 two-price program, farmers' income would decline below that predicted under a continuation of current farm programs unless the export elasticity were above 4. Supporting wheat for food and industrial use at $10 rather than at $7 per bushel would depress farm prices even more because of lower food and industrial use. But, the negative effect on gross income would be offset by larger direct payments.

Wheat production and use would vary only marginally from their respective values under the $7/$2.50 two-price program. The farm price of wheat would average 2-3 cents per bushel lower compared with the previous program, and gross farm income would average $1.5-1.6 billion per year higher (table 7). Compared with the baseline, the $10/$2.50 two-price program would increase gross farm income if the export elasticity were above about 0.5. Farmers' net income would average from about $650 million lower to about $420 million higher per year than under a continuation of current programs. Farmers' net income would average about $512 million lower per year if the export elasticity were 0.5. CCC net outlays would decline to about $1.1 billion per year. Thus, CCC net outlays would average over $3.1 billion per year lower than under a continuation of current programs.

The costs of supporting farmers' income would be shifted from taxpayers to consumers. Compared with the baseline, consumer expenditures for bakery products would average about $3.7 billion per year higher, which more than offsets the decline in CCC net outlays if the export elasticity fails to exceed 1.50. If the export elasticity were 0.5, the total cost (taxpayer plus consumer) of supporting farm income exceeds its baseline value by about $568 million per year.

Comparing tables 6 and 7 reveals that if the export elasticity were below 1.1 and if the support price on wheat for food and industrial use were increased, the total (consumer plus taxpayer) cost of supporting farmers' income would rise faster than farmers' net income. If the export elasticity were above 1.1, the increase in farmers' net income would exceed the increase in total support costs. Even if the export elasticity were 4, farmers' net income would increase by only $1.04 for each $1 increase in consumer expenditures.

Conclusions

Because the export wheat market is generally more responsive to changes in price than the domestic wheat market, economic theory suggests that we could increase farmers' revenues by segmenting the two markets (domestic and international) and by setting a high support price on wheat for domestic use and a lower support price on wheat for export. Stated differently, economic theory suggests we could increase farmers' revenues if we subsidize wheat exports and tax wheat for domestic use. Of course, if farmers' revenues are increased through the marketplace, the public costs of supporting farmers' incomes would probably fall. From a budgetary viewpoint, such a program is particularly appealing because both farmers and taxpayers might be better off.

The simulation results indicate that a federally funded export sudsidy of 50 cents to $1 per bushel combined with current production control programs would strengthen farm prices and would increase farmers' incomes. Deficiency and diversion payments would decline, but total Government program outlays would increase unless the export elasticity is nearly 1 or higher. Higher farm prices also translate into higher consumer expenditures for wheat products. And, if we calculate the total costs of supporting farmers' incomes as the sum of the change in consumer expenditures and taxpayer costs, the export elasticity must be greater than 1 before the costs of supporting farmers' incomes would decline. The results indicate that, compared with a continuation of current programs and assuming an export elasticity of 1 for U.S. wheat, a 50-cent per bushel subsidy would increase farmers'

Table 7—Effects of a \$10/\$2.50 two-price program[1]

Item	Unit	Baseline	Export elasticities				
			−0.25	−0.50	−1.00	−2.00	−4.00
Acreage planted	Million acres	72.52	80.48	80.80	81.18	81.93	82.81
Acreage harvested	do.	65.27	72.49	72.78	73.12	73.80	74.61
Yield per acre	Bushels	41.00	37.87	37.86	37.84	37.80	37.76
Supply:	Million bushels						
Beginning stocks	do.	2,183.07	2,175.30	2,030.03	1,795.30	1,527.85	1,415.87
Production	do.	2,674.25	2,742.56	2,752.70	2,764.27	2,787.88	2,815.64
Imports	do.	3.00	3.00	3.00	3.00	3.00	3.00
Total	do.	4,860.32	4,920.86	4,785.73	4,562.58	4,318.73	4,270.51
Use:							
Food and industry	do.	678.99	595.63	595.63	595.63	595.63	595.63
Seed	do.	91.21	100.99	101.39	101.85	102.77	103.86
Feed	do.	254.80	337.46	320.29	322.75	304.88	284.37
Exports	do.	1,382.14	1,461.43	1,526.93	1,643.00	1,766.31	1,835.16
Total	do.	2,407.15	2,495.50	2,554.25	2,663.22	2,769.60	2,819.02
Ending stocks	do.	2,453.18	2,425.36	2,231.50	1,899.35	1,549.14	1,451.49
Price	Dollars per bushel	3.33	2.57	2.63	2.70	2.87	3.06
Income indicators:	Million dollars						
Value of production	do.	8,909.74	7,038.03	7,246.16	7,468.72	7,994.76	8,609.00
Deficiency payments	do.	1,920.07	4,427.42	4,388.10	4,347.20	4,248.29	4,135.04
Storage payments	do.	152.41	146.76	137.45	130.37	110.99	83.38
Diversion payments	do.	789.26	0	0	0	0	0
Total gross income	do.	11,771.47	11,612.21	11,771.71	11,946.29	12,354.05	12,827.42
Variable expenses	do.	4,485.36	4,977.68	4,997.48	5,020.98	5,067.37	5,121.80
Total net income	do.	7,286.11	6,634.52	6,774.23	6,925.31	7,286.68	7,705.62
Net CCC outlays:[2]							
Deficiency payments	do.	1,770.90	0	0	0	0	0
Diversion payments	do.	791.69	0	0	0	0	0
Storage payments	do.	150.33	145.00	135.65	128.76	110.60	83.67
Net lending	do.	931.41	597.89	462.65	211.79	−42.76	−120.29
Export subsidy	do.	0	0	0	0	0	0
Other	do.	558.37	526.71	476.62	380.60	280.22	280.22
Total	do.	4,202.69	1,269.60	1,074.93	721.16	348.06	243.60
Consumer expenditures[3]	do.	37,783.45	41,478.71	41,478.71	41,478.41	41,478.71	41,478.41

[1] Unless indicated otherwise, numbers are crop year 1985/86 to 1991/92 averages.

[2] Fiscal year 1986-91 averages.

[3] For bakery products.

net incomes by about $65 million per year (less than 1 percent) while lowering CCC net outlays by $37 million per year (less than 1 percent) and raising consumer expenditures by $108 million (less than 1 percent) per year. A $1-per-bushel subsidy (again assuming an export elasticity of 1) would increase farmers' net incomes by about $81 million while lowering CCC net outlays by $46 million and raising consumer expenditures by $152 million. Thus, subsidizing exports by as much as $1 per bushel will only moderately increase wheat farmers' net income.

Relaxing production controls while simultaneously subsidizing exports by $1.50 per bushel would reduce CCC net outlays by $195 million to $1.1 billion per year for FY 1986/87 to 1991/92. Despite the export subsidy, farmers' net income would fall unless the export elasticity were above about 3.5. Assuming an export elasticity of 1 and no production controls, a $1.50-per-bushel sudsidy would reduce farmers' net income by over $2 billion per year, CCC net outlays would fall by about $1.1 billion, and consumer expenditures would increase by $171 million per year compared with a continuation of current programs.

Establishing a high support price for wheat for food and industrial use and a low support price for wheat for export and other domestic uses may not benefit wheat producers. If production controls are eliminated, setting the support price for food and industrial use at $7 per bushel and the support price for export and other domestic uses at $2.50 per bushel could substantially reduce farmers' net income. For example, if the export elasticity were 1, net farm income would average $1.9 billion per year lower, CCC net outlays would average $3.6 billion per year lower, whereas consumer expenditures would average nearly $2.2 billion per year higher compared with a continuation of current programs.

Finally, a $10/$2.50 two-price program would increase farmers' net income if the export elasticity is greater than 2. CCC net outlays would decline by about $3-4 billion per year compared with a continuation of current programs. However, consumer expenditures would increase by about $3.7 billion per year.

Past studies generally suggest the elasticity of U.S. wheat exports is less than 2. Thus, subsidizing U.S. wheat exports will probably increase wheat producers' incomes only moderately, especially if the cost of supporting farmers' incomes by taxpayers and consumers is not permitted to increase significantly. Put more simply, export subsidy programs cannot provide large positive benefits to producers while simultaneously lowering the direct and consumer costs of supporting farmers' incomes. In addition, a policy of across-the-board export subsidies would probably cause the United States to lose some of its ability to influence other countries to reduce and eliminate protectionist policies. Competitor countries could, of course, retaliate by further expanding their subsidy programs or by reducing imports of U.S. agricultural and nonagricultural commodities. Export subsidy programs should not necessarily be shelved altogether. Targeted export subsidies may indeed provide positive benefits to producers as well as lower consumer and taxpayer costs of supporting farmers' incomes if targeted at countries with import demand elasticities above 2. Export subsidies may be necessary to maintain the U.S. share of the world wheat market and to force major competitors to rethink their export policies.

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Measuring Implicit Rental Rates for Farm Capital

By James Hrubovcak*

Abstract

Developing implicit rental rates for capital inputs is an important step in understanding the impact of tax law changes on agricultural investments. This article develops a methodology for estimating implicit rental rates and presents annual estimates of rental rates for seven categories of farm equipment and structures from 1955 to 1979. This article also compares these rental rates with those estimated under a no-tax alternative. The author developed a method for estimating marginal Federal income tax rates for farm sole proprietorships.

Keywords

Implicit rental rate, marginal tax rate, investment, depreciation, capital

Introduction

Federal income tax regulations are important determinants of which assets make up the capital stock. However, taxes only affect the mix of the capital stock if the effects of tax laws are not neutral toward all assets—that is, if they distort the relative after-tax prices of assets. In the absence of other distortions, if tax provisions such as accelerated methods of depreciation, short tax lives, and the investment tax credit lower the after-tax price of some assets more than others, investors are encouraged to purchase more of the affected assets (*5*).[1] Any resulting change in the capital stock may lower economic efficiency as investors are responding to tax factors rather than market factors.

One way to analyze the effects of changes in tax laws on the mix of capital inputs is to compare implicit rental rates for various assets. Rental rates differ from asset prices in that they measure the cost of a flow of a capital service during a specific period. Rental rates are a function of the prices of assets, rates of economic or capacity depreciation, tax variables, the discount rate, and the rate of inflation. Rental rates are the cost of capital services that are internally supplied by the firm (*5*). Therefore, as tax variables are changed, so is the cost of supplying capital services and the demand for those services.

This article presents annual estimates of the marginal income tax rates of farm sole proprietorships and rental rates for seven categories of farm equipment and structures from 1955 to 1979 in an attempt to improve the current understanding of how Federal income tax policy affects the level of agricultural investment.

Estimating Implicit Rental Rates

The implicit rental price of a unit of capital service is the after-tax cost of the capital service that is internally supplied by the firm. When the firm is treated as a lessor of capital services, the rental rate is the price the firm will charge for each unit of capital services leased. Therefore, the implicit rental rate is the rate the firm must charge to earn a required after-tax rate of return. The rental rate is a function of the price of the asset, the rate of capacity depreciation, the tax variables, the discount rate, and the rate of inflation. True rental rates are directly observed from market transactions with active rental markets. Implicit rental rates are estimates of the true rental rates that would prevail under given sets of assumptions. Nonneutral tax-induced changes in rental rates affect the capital stock as lower taxed capital inputs are substituted for higher taxed capital inputs. Assuming perfectly competitive market conditions and cost-minimizing behavior, firms adjust their stocks of capital inputs until the ratio of the marginal products of any pair of inputs equals the ratio of their respective rental rates. To the degree that inputs are substitutable, a change in tax law which decreases the rental rate of one input relative to other inputs will increase the demand for the lower priced input until the cost-minimization conditions are satisfied. This situation does not imply that the same tax treatment is appropriate for each type of asset. In the presence of an otherwise neutral income tax system, inflation can bias the mix of inputs used. Because tax depreciation deductions are based on the historical cost of assets, inflation reduces the real value of the nominal deductions, with the reduction being the greatest for shorter lived assets (*8*). During inflation, the use of historical cost tax depreciation for all assets increases demand for long-lived assets relative to assets with shorter lives.

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

A formula for implicit rental rates can be developed from the equality between the purchase price of an asset and the present value of the future rents generated by the asset (*9*). Assuming constant new asset price expectations and allowing for alternative depreciation patterns, the basic Jorgenson equation converted to discrete time is:

$$q_i = \sum_{t=1}^{L_i} u_i a_i(t)/(1 + r)^t \qquad i = 1,2,\ldots,m \qquad (1)$$

where q_i is the purchase price of the ith asset when new, L_i is the service life of the asset, u_i is the rental rate for a new (undepreciated) unit of capital, $a_i(t)$ is the capacity of a unit of capital in year t of its service life, and r is the discount rate. The capacity of the asset is 1 in period 1 and declines over its service life as a function of the rate of capacity depreciation.

Equation (1) ignores all tax considerations. When capital income is subject to an income tax, the term on the right side of equation (1) must be modified and expanded to include the effects of the tax. The expanded term included expressions for the present value of the after-tax rents generated by the asset and for the present value of the tax savings produced by the investment tax credit and tax depreciation deductions. Assuming the firm's marginal tax rate remains constant as T, equation (1) respecified to accommodate the tax system becomes:

$$q_i = (1 - T)u_i A_i + C_i q_i + T(1 - dc_i)B_i q_i \qquad (2)$$
$$i = 1,2,\ldots,m$$

where $(1 - T)u_i A_i$ is the present value of the after-tax rents, $C_i q_i$ is the present value of the tax saving produced by the investment tax credit, and $T(1 - dc_i)B_i q_i$ is the present value of the tax saving produced by tax depreciation deductions.

With constant price expectations and a constant marginal tax rate, the rental rate remains constant over the life of the asset. The capacity of the asset, however, declines over the life of the asset so that:

$$A_i = \sum_{t=1}^{L_i} a_i(t)/(1 + r)^t \qquad i = 1,2,\ldots,m \qquad (3)$$

where r is the discount rate which is the real after-tax rate of return required by the firm.

Although the firm pays taxes on the rents generated by each asset, the firm is also allowed to deduct the decline in the value of the asset as an expense. If the present value of the depreciation deductions claimed for tax purposes is equal to the true decline in market value for each asset, the tax system does not bias investment toward any asset.

If $b_i(t)$ is the fraction of the price of the ith asset that is deducted from taxable income in year t of the asset's tax life (M_i), the present value of the tax depreciation is $TB_i q_i$, where:

$$B_i = \sum_{t=1}^{M_i} b_i(t)/(1 + r)^t(1 + p)^t \qquad i = 1,2,\ldots,m \qquad (4)$$

and p is the rate of inflation. However, in some years the tax depreciation base was reduced by the amount of the investment tax credit. Therefore, a more general expression for the present value of tax depreciation deductions is $T(1 - dc_i)B_i q_i$, where d is the percentage of the credit, if any, which must be used to reduce the tax depreciation base. In addition to the depreciation deductions, firms may also be eligible to claim an investment tax credit (c). If firms claim the credit at the end of the first year of the asset's service life, the present value of the credit is $C_i q_i$, where:

$$C_i = c_i/(1 + r)^1(1 + p)^1 \qquad i = 1,2,\ldots,m \qquad (5)$$

Given the market price of the asset, equation (2) can be rewritten as:

$$u_i = q_i[1 - C_i - T(1 - dc_i)B_i]/A_i(1 - T) \qquad (6)$$

$$i = 1,2,\ldots,m$$

to solve for the implicit rental rate (u_i) that the firm must charge to earn the required real after-tax rate of return (r).[2] Equation (6) can also show how changes in tax laws may affect the rental rate. For example, an increase in the real value of the investment tax credit, through a change in tax laws or a reduction in the inflation rate, will decrease the rental rate. This decreased rental rate is observable by differentiating equation (6) with respect to the present value of the investment tax credit:[3]

$$\partial u_i/\partial C_i = -q_i/A_i(1 - T) < 0 \qquad i = 1,2,\ldots,m \qquad (7)$$

Because $q_i > 0$, $A_i > 0$, and $0 < T < 1$, the derivative $\partial u_i/\partial C_i < 0$.

Similarly, equation (8) shows that an increase in the present value of the tax depreciation deductions also reduces the rental rate.

$$\partial u_i/\partial B_i = -q_i T/A_i(1 - T) < 0 \qquad i = 1,2,\ldots,m \qquad (8)$$

A change in the marginal income tax rate with respect to the rental rate, however, results in ambiguous effects:

$$\partial u_i/\partial T = q_i(1 - C_i - B_i)/A_i(1 - T)^2 \qquad (9)$$

$$i = 1,2,\ldots,m$$

For example, a tax rate reduction reduces the tax on the rents generated by the asset and also reduces the value of the tax depreciation deductions. In most cases, decreasing the tax rate will lower the rental rate. However, equation (9) shows that decreasing the marginal income tax rate (T) increases the rental rate, provided $C_i + B_i > 1$. In other words, a decrease in the tax rate will cause rental rates to rise if the purchase price of the asset is less than the present value of the investment tax credit plus the present value of tax depreciation deductions. If the purchase price is less than the present value of the credit and the depreciation deductions, the Government returns more than a dollar to the firm in tax saving for every dollar of investment.

Data

As stated earlier, implicit rental rates are estimates of true rental rates that would exist under a given set of assumptions. Therefore, it is important that I discuss the rationale for these assumptions, especially those regarding the economics characteristics of the assets, the tax parameters, and the discount rate.

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[2] The rental rate in equation (6) assumes the asset is completely depreciated and, therefore, could not be sold at the end of its service life. However, equation (6) could be generalized to consider any salvage value and the tax consequences of a sale.

When an asset is sold for an amount less than or equal to the original purchase price, the proceeds from the sale must be recaptured as ordinary income, with the present value of the proceeds (P) equal to:

$$P = [1 - T][q(1 + g)^L/(1 + r)^L(1 + p)^L]$$

where g is the nominal growth rate in used asset prices.

When an asset is sold for an amount greater than the original purchase price, that portion of the proceeds equal to the original purchase price must still be recaptured as ordinary income, and only the amount in excess of the purchase price is considered a capital gain for tax purposes. The present value of the capital gain (G) can be represented as:

$$\begin{aligned} G = {} & [(q(1 + g)^L - q)/(1 + r)^L(1 + p)^L] \\ & - T(1 - j)[(q(1 + g)^L - q)/(1 + r)^L(1 + p)^L] \end{aligned}$$

where the first part of the equation is the capital gain portion of the sale and the second part of the equation is the tax on the capital gain with j being the capital gains exclusion.

Including both the ordinary income generated by the sale and the capital gain, if any, equation (6) can be recast as:

$$u = [q[1 - C - T(1 - dc)B]/A(1 - T)] - P - G$$

[3] For simplicity, I assumed that the investment tax credit did not affect the basis for depreciation purposes.

Economic Characteristics of Assets

I estimated rental rates for autos, trucks, tractors, long-lived farm equipment, crop storage structures, multipurpose structures, and unitary livestock facilities. Asset price indexes for each of the four farm machinery categories were set equal to the respective Bureau of Labor Statistics (BLS) price index for passenger cars, trucks, wheel-type farm tractors, and agricultural machinery excluding farm tractors (*20*). A single price index series for all three structure categories was taken from the Bureau of Economic Analysis (BEA) capital stock study (*19*).

The service lives for each equipment category are based on averages of Bulletin F depreciation lives and are taken from Ball (*1*). The service lives for autos, trucks, tractors, and other long-lived equipment are 12, 11, 9, and 20 years, respectively.[4] Unitary livestock facilities and multipurpose agricultural structures had service lives of 50 years, whereas the service life of crop storage structures was 25 years.

The rate of economic depreciation for each category is approximated by the double-declining balance depreciation method where the capacity of the ith asset in year t of the asset's service life (L_i) is represented as:

$$a_i(t) = [1 - (2/L_i)]^{t-1} \qquad i = 1,2,\ldots,m \qquad (10)$$

for $1 \leq t \leq L_i$, and $a_i(t) = 0$ for $t > L_i$. To test the sensitivity of the capacity depreciation assumption, I also estimated rental rates assuming a "one-hoss shay" depreciation pattern (see appendix) where the capacity of the ith asset in year t is represented as:

$$a_i(t) = 1 \qquad i = 1,2,\ldots,m \qquad (11)$$

for $1 \leq t \leq L_i$, and $a_i(t) = 0$ for $t > L_i$. These rental rates are presented in the appendix of this article.

Tax Lives, Investment Tax Credit, and Tax Depreciation Methods

The tax lives selected by farmers are based on the allowable lives which result in the greatest tax saving over the service life of the asset. Greatly affecting the tax life, however, was the eligibility of the asset for the investment tax credit. From 1962 to 1968 and again from 1971 to 1974, eligible assets (each machinery category and crop storage structures) with a useful life of at least 8 years received the full 7-percent investment tax credit.[5] Eligible assets with a tax life of 6 or 7 years received two-thirds of the 7-percent credit. From 1975 to 1979, the investment tax credit was increased to 10 percent, and the tax life requirement for each level of the credit was reduced by 1 year. The tax savings associated with the investment tax credit was enough to offset the savings from selecting shorter tax lives. As a result, I assumed that farmers selected the minimum allowable tax life which qualified for the entire investment tax credit. Table 1 presents the tax lives for each category.

Table 1—Tax lives for each asset category

Asset category	Tax life				
	1955-61	1962-68	1969-70	1971-74	1975-79
	Years				
Autos	6	8	3	8	7
Trucks	6	8	4	8	7
Tractors	10	10	10	8	8
Long-lived farm equipment	15	10	10	8	8
Crop storage structures	25	10	10	8	8
Unitary livestock facilities	50	25	25	20	20
Multipurpose structures	50	25	25	20	20

The tax depreciation methods chosen were also based on the tax savings generated by each of the allowable methods.[6] From 1955 to 1969, assets in each category could have been depreciated under the sum-of-year's-digits method or the double-declining balance method. Under both alternatives, a portion of an asset could be depreciated at the straight line rate if the switch resulted in larger depreciation deductions. The sum-of-year's digits with a switch to the straight line rate resulted in the greatest tax savings and was the selected method for each category. From 1970 to 1979, each machinery category and crop storage structure were allowed the same accelerated depreciation methods allowed prior to 1970. However, unitary livestock structures and multipurpose structures were limited to a depreciation rate equal to 150 percent of the straight line rate.

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[4] Although the 9-year economic life of tractors is consistent with Bulletin F, some studies indicate that their economic life may be longer (*11*). Therefore, rental rates for farm tractors with a 12-year economic life have also been estimated.

[5] Unitary livestock facilities became eligible for the credit in 1971.

[6] Although not all farmers select a single depreciation pattern, data do not allow us to determine which methods are employed and to what extent each method is used. To be consistent, I chose the option which resulted in the lowest rental rate.

Discount Rate

I also had to specify the discount rate used to calculate the present value of the rents, investment tax credit, and the tax depreciation deductions; the discount rate is the opportunity cost to the investor of purchasing the asset. As discussed by Eisner and Strotz (*3*), the appropriate interest rate used to represent the opportunity cost does not fall short of the investment horizon. The discount rate used for equipment and structures is, therefore, a weighted average of the longrun real after-tax interest rate (external financing) and the expected longrun real after-tax return to equity (internal financing). Nominal interest charges are deductible from taxable income, and inflation reduces the real value of nominal interest and principal payments on debt. When these two factors are considered, the real cost of external or debt financing (r_d) is:

$$r_d = [r_n(1 - T) - p]/(1 + p) \tag{12}$$

when r_n is the nominal interest rate. After the real costs of both equity and debt financing are combined, the real cost of capital or real discount rate is:

$$r = fr_d + (1 - f)r_e \tag{13}$$

where f is the fraction debt financed, r_d is the real after-tax cost of debt financing, and r_e is the real after-tax return to equity (*13*).

Data from the 1969 and 1979 Farm Finance Surveys (*17, 18*) indicate that the fraction of farm investment that is debt financed is about 50 percent. In keeping with Eisner and Strotz' theory that the appropriate interest rate should be a longrun rate, interest rates for external financing were rates charged by Federal Land Banks on new farm loans (*14, 16*). Following Coen (*2*) and Penson, Romain, and Hughes (*11*), I assumed the longrun real after-tax rate of return to equity was constant for each asset over the period studied. Although there are few data regarding the appropriate longrun real after-tax return to equity, Melichar found that the real total return to farm assets since 1950 has averaged about 8 percent (*10*). Gertel also found that the real before-tax return to cash rented farmland averaged 8.1 percent from 1940 to 1980 (*4*). Therefore, for this analysis I decided to use a real after-tax return to equity of 6 percent.[7]

One can also respecify the discount rate to account for State and local property taxes. If the property tax is correctly assessed, the property tax variable can be specified explicitly in the rental price equation or, because it increases the cost of capital, the variable can be specified in the discount rate (*7*). Accounting for the deductibility of property taxes from the Federal income tax and the fact that property taxes are generally levied in the current year but payable in the next year, I recast equation (13) as:

$$r = fr_d + (1 - f)r_e + [(1 - T)K/(1 + p)] \tag{14}$$

where K is the property tax rate expressed as a percentage of the value of the asset.

Because many States exempt farm personal property from taxation, I assumed that property taxes were levied only on the three structure categories. Property tax rates were taken from U.S. Department of Agriculture (USDA) estimates of farm real estate taxes (*6*).

Marginal Income Tax Rates

Finally, I developed an average marginal Federal income tax rate for new farm investment. The marginal tax rate is the expected tax that an investor or firm would pay on an additional dollar of income prior to undertaking any new investment. This tax rate is used to determine the rental rates for farm capital. It was necessary to create an average farm sole proprietorship Federal income tax return for the years data were available to estimate this marginal tax rate. Starting with adjusted gross income, I replaced the amount of depreciation and interest deductions claimed for new investment. After dividing by the number of businesses and subtracting the personal exemption, dependent credit, and, if applicable, the standard deduction or zero bracket amount, I estimated average taxable income.[8] One can estimate the average marginal income tax rate by comparing the average taxable income with the appropriate tax table.

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[7] The appendix to this article shows rental rates for long-lived farm equipment under returns to equity of 3 percent and 9 percent.

Adjusted Gross Income. Adjusted gross income is gross income from all taxable sources reduced by adjustments such as the ordinary and necessary expenses of operating a trade or business. Therefore, adjusted gross income combines both onfarm and off-farm income less total depreciation, interest, and other allowable farm business expenses. Except for 1964 and 1965, the Internal Revenue Service (IRS) has published annual data on adjusted gross income for farm sole proprietorships from 1962 to 1979 (*22*). I used adjusted gross income rather than a narrower definition of income such as net income from farming because onfarm and off-farm income are interrelated. Off-farm income finances farm investment, and farm-related expenses offset off-farm income.

Tax Depreciation Deductions. Historically, IRS only publishes total depreciation deductions claimed in the current year, but it publishes neither data on farm investment nor allowances for depreciation deductions claimed on new investment. Therefore, to calculate the marginal tax rate, I had to develop a procedure for separating the amount of depreciation claimed on new investment in the current year from depreciation deductions carried forward from investment in prior years. Therefore, I depreciated investment data for trucks, tractors, other farm equipment, and structures published by USDA (*15*) over the selected tax lives. Because there are no data regarding the actual depreciation method selected by farmers, I assumed that farmers selected the depreciation method and tax life which resulted in the greatest amount of tax savings over the economic life of each asset.

Using investment data provided by USDA and the assumed tax life and depreciation method, I calculated the total farm depreciation pattern including the amount claimed on new investment in the current year. I applied the percentage of first-year depreciation to IRS-published data on total depreciation deductions to estimate the IRS depreciation deductions claimed on new investment. Except for 1968 and 1969 (during which the stimulus of the investment tax credit was only partially in effect), the percentage of tax depreciation deductions claimed for new investment in the first year increased steadily through time (table 2). Much of this increase results from increases in the nominal amount of investment rather than from changes in tax laws. For example, gross farm capital expenditures, excluding farm households, increased from $4.5 billion in 1962 to $6.8 billion in 1967; it then fell to $6.1 and $6.2 billion in 1968 and 1969, respectively.

Although the level of investment appears to be the most significant determinant of first-year depreciation, certain tax law changes have also had an impact. In 1958, the introduction of the additional first-year depreciation option allowed an additional deduction of 20 percent of eligible investment. Revenue Procedure 62-21, enacted in 1962, significantly shortened the existing Bulletin F tax lives for many assets (*23*). In 1971, the Asset Depreciation Range (ADR) System allowed taxpayers to further reduce tax lives by 20 percent (*21*). However, the impact of reducing tax lives may have been limited because choosing the shorter tax life may have decreased the investment tax credit or eliminated the additional first-year depreciation deduction.

Interest Paid Deduction. IRS publishes the total interest-paid deduction and does not separate interest expenses incurred for investment. Therefore, I assumed that all IRS interest expenses were attributable to investment. Furthermore, I calculated the percentage of interest charges on new debt using the data and methodology employed by USDA to estimate interest charges on farm real estate

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[8] Because Schedule Y, the tax table used for this analysis, incorporates the standard deduction, there is no need to explicitly consider the standard deduction.

Table 2—Gross farm investment, percentage of total tax depreciation deductions from new investment, total IRS tax depreciation, and IRS tax depreciation from new investment, 1962-79

Year	Gross farm investment	Total tax depreciation resulting from new investment	Total IRS tax depreciation deduction, sole proprietorships	IRS depreciation resulting from new investment
	Million dollars	*Percent*	*Million dollars*	
1962	4,473	27	3,177	858
1963	4,846	30	3,175	953
1964	5,101	32	3,253	1,041
1965	5,566	33	3,443	1,136
1966	5,095	35	3,693	1,292
1967	6,836	36	3,915	1,410
1968	6,112	32	4,126	1,320
1969	6,214	31	4,439	1,376
1970	6,793	32	4,598	1,471
1971	6,789	34	4,824	1,640
1972	7,480	36	5,290	1,905
1973	10,172	42	6,473	2,719
1974	11,444	42	7,189	3,019
1975	12,384	41	7,857	3,221
1976	13,968	42	8,845	3,715
1977	15,015	41	8,758	3,591
1978	17,948	43	10,208	4,389
1979	19,874	44	11,241	4,946

debt.[9] I then applied that percentage to the IRS data on the interest-paid deduction to estimate the interest expenses resulting from new investment.

Because the procedure used by USDA to estimate interest charges on real estate debt has already been explained in detail (*12*), only an overview will be presented here. Loan and contractual interest rate data are from Federal land banks, life insurance companies, Farmers Home Administration, commercial banks, and individuals and others. Loans outstanding at the beginning of each year and new loans made during the year are from primary sources (Farm Credit Administration, American Council of Life Insurance Companies, the Farmers Home Administration, and the Federal Deposit Insurance Corporation), except for loans from individuals and others which are benchmarked on Census of Agriculture data. Data on interest rates are more tenuous in that the average interest rates on loans outstanding are all estimates, except for Federal land banks and the Farmers Home Administration. Interest rates on new loans are based on surveys conducted by USDA and the Farm Credit Administration.

I estimated total interest charges for each year by multiplying the average loans outstanding during the year for each year for each lender by the appropriate average interest rate on loans outstanding. Multiplying the average interest rate on new loans by lender by the amount of new loans made during the year yields an estimate of interest charges resulting from new investment. I then multiplied the percentage of total interest charges representing new investment by the IRS data on interest expenses to estimate the amount of interest expenses from debt incurred on new investment.

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[9] I considered only the USDA real estate debt series to exclude the short-term production loans contained in the nonreal-estate debt category. The nonreal-estate debt category contains loans for recurring production items such as feed and seed. Because these loans are short term, the percentage of interest expenses on new loans relative to total interest expenses would be large and would inflate the percentage of total interest charges resulting from new investment.

Table 3—Percentage of interest charges from new investment, total IRS interest charges, and total IRS interest from new investment, 1962-79

Year	Total interest charges resulting from new investment	Total IRS interest deduction, sole proprietorships	IRS interest deductions resulting from new investment
	Percent	*Million dollars*	
1962	30	902	269.10
1963	32	997	316.42
1964	32	1,064	340.79
1965	32	1,160	365.54
1966	31	1,358	414.50
1967	27	1,507	407.47
1968	26	1,708	439.64
1969	26	1,834	479.81
1970	24	2,035	487.16
1971	27	2,207	588.06
1972	34	2,459	829.48
1973	41	2,915	1,194.75
1974	38	3,256	1,219.47
1975	33	3,865	1,289.09
1976	33	4,595	1,528.80
1977	36	4,777	1,730.05
1978	28	5,872	1,636.00
1979	30	7,243	2,173.00

Table 3 shows estimates of the percentage of the total interest charges which represents interest charges on new investment, the IRS estimate of total interest deductions, and the estimated amount of IRS interest deductions resulting from new investment.

Estimating Marginal Tax Rates. The final step in the estimation procedure was to sum adjusted gross income and the total tax depreciation and interest expenses resulting from new investment; I then divided that total by the number of farm business returns to estimate adjusted gross income per return. I then reduced per-return adjusted gross income by the personal exemption and dependent credit to estimate taxable income.[10] I then estimated the marginal tax rate by comparing taxable income with the appropriate tax table. Table 4 presents per-return adjusted gross income (including tax depreciation and interest expenses on new investment), taxable income, and marginal income tax rate from 1962 to 1979.[11]

The marginal tax rate declined from 20 percent in 1962 and 1963 to 17 percent in 1965; it then increased to a high of 25 percent in 1978 (table 4). However, the decline in marginal tax rate from 1963 to 1965 was caused by the Revenue Act of 1964 rather than by a drop in taxable income. The

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[10] In addition to the personal exemption, I assumed that each return claimed three dependents. Since 1955, both the personal exemption and the dependent credit have been equal; they increased from $600 in 1955 to $625 in 1970, to $675 in 1971, to $750 in 1972, and to $1,000 in 1979.

[11] An example of the procedure for 1979 is as follows:

Farms total, returns with and without adjusted gross income	
Adjusted gross income	$56,636,323,000
+Depreciation on 1979 investment ($11,241,468,000*0.44)	$4,946,245,920
+Interest on 1979 investment ($ 7,242,712,000*0.30)	$ 2,172,813,600
	$63,755,382,520
÷Number of returns	2,921,934
	$21,820
−Personal exemption and three dependents	$4,000
Taxable income	$17,820

Table 4—Per return, adjusted gross income, taxable income, and marginal income tax rates, 1962-79

Year	Per return adjusted gross income	Per return taxable income	Per return marginal income tax rates
	Dollars		*Percent*
1962	4,853.33	1,968.00	20
1963	5,033.17	2,129.85	20
1964	5,907.53	2,916.78	20
1965	6,718.01	3,646.21	17
1966	7,028.83	3,935.39	17
1967	7,381.25	4,243.12	19
1968	8,128.65	4,915.78	19
1969	8,633.66	5,370.29	19
1970	8,869.38	5,482.44	19
1971	9,507.02	5,571.11	19
1972	11,404.88	6,694.15	19
1973	13,765.56	8,765.56	22
1974	14,311.56	9,311.56	22
1975	14,626.73	9,626.73	22
1976	15,814.81	10,442.59	22
1977	14,661.82	11,661.82	22
1978	19,833.01	16,833.01	25
1979	21,819.58	17,819.58	24

Revenue Act of 1964 reduced marginal income tax rates and narrowed the tax brackets, substantially increasing the progressiveness of the Federal income tax system. For example, the minimum marginal tax rate in 1963 was 20 percent, and each tax bracket increased at $2,000 intervals below $22,000 in taxable income. The minimum marginal tax rate was reduced to 14 percent in 1965, and the first four tax brackets were increased at $500 intervals.

The lack of progressivity in the tax system prior to the Revenue Act of 1964 allows the estimation of marginal income tax rates prior to 1962. Because the lowest marginal tax rate applied was to taxable income below $2,000, the appropriate marginal tax rate would be the one which corresponded to the lowest tax bracket. Therefore, the marginal tax rate from 1955 to 1961 was 20 percent. For 1964 and 1965, I used USDA data (*15*) for onfarm and off-farm income as a proxy for adjusted gross income; the estimated marginal tax rate for 1964 was 20 percent, and the tax rate fell to 17 percent in 1965.

Results

Rental rates for short-lived assets such as autos, trucks, and tractors are significantly higher than those for long-lived assets such as long-lived equipment and structures (table 5). The higher rental rates are primarily the result of shorter economic lives of the assets rather than of differences in tax treatment. The first major tax change during the period studied was the introduction of the investment tax credit in 1962. From 1961 to 1962, the rental rates fell from 0.1617 to 0.1489 for autos, from 0.1404 to 0.13 for trucks, from 0.1301 to 0.1236 for tractors (with a 9-year economic life), from 0.1029 to 0.0976 for tractors (with a 12-year economic life), from 0.0705 to 0.0656 for long-lived equipment, and from 0.0592 to 0.0533 for crop storage structures. The fall in rental rates for autos and trucks was also moderated by the required use of a minimum 8-year tax life to qualify for the entire 7-percent credit. Because the benefits of the credit outweighed the cost of selecting the longer life, I assumed that the tax lives of autos and trucks were increased from 6 to 8 years. Unitary livestock facilities and multipurpose structures were not eligible for the investment tax credit when it was first introduced in 1962.

In 1969 and 1970, the investment tax credit was repealed, and the rental rates for those assets which had previously qualified for the credit increased significantly. The rental rate for autos increased from 0.1417 in 1968 to 0.1510 in 1969, and the rental rate for trucks increased from 0.1312 to 0.1426. The rental rates for both tractor categories and long-lived equipment increased from 0.1384 to 0.1562, from 0.1081 to 0.1219, and from 0.0716 to 0.0797, respectively. The rental rates for unitary livestock facilities and multipurpose structures also increased from 1968 to 1969. However, these increases were a result of the rise in the price index of structures rather than the result of changes in tax laws.

In 1971, the investment tax credit was reinstituted, and unitary livestock facilities were added to the list of assets eligible to receive the credit. IRS also introduced the Asset Depreciation Range (ADR) system. Under the ADR system, tax lives could be reduced by as much as 20 percent. However, rising asset prices moderated the reduction in rental rates

Table 5—Implicit rental rates for farm equipment and structures, 1955-79

Year	Autos	Trucks	Tractors (9)[1]	Tractors (12)[2]	Long-lived farm equipment	Unitary livestock facilities	Crop storage structures	Multipurpose agricultural structures
					Rate			
1955	0.1408	0.1173	0.1062	0.0838	0.0567	0.0393	0.0554	0.0393
1956	.1418	.1216	.1055	.0824	.0551	.0369	.0548	0369
1957	.1497	.1299	.1124	.0880	.0588	.0381	.0558	.0381
1958	.1566	.1368	.1186	.0933	.0627	.0403	.0567	.0403
1959	.1617	.1419	.1241	.0978	.0660	.0411	.0573	.0411
1960	.1612	.1395	.1265	.0999	.0685	.0417	.0576	.0417
1961	.1617	.1404	.1301	.1029	.0705	.0433	.0592	.0433
1962	.1489	.1300	.1236	.0976	.0656	.0410	.0533	.0410
1963	.1470	.1282	.1247	.0983	.0661	.0411	.0538	.0411
1964	.1453	.1268	.1259	.0994	.0670	.0426	.0545	.0426
1965	.1426	.1265	.1268	.0999	.0672	.0424	.0553	.0424
1966	.1384	.1247	.1288	.1009	.0670	.0415	.0556	.0415
1967	.1410	.1285	.1342	.1053	.0705	.0448	.0591	.0448
1968	.1417	.1312	.1384	.1081	.0716	.0451	.0607	.0451
1969	.1510	.1426	.1562	.1217	.0797	.0492	.0723	.0492
1970	.1596	.1534	.1671	.1309	.0859	.0582	.0816	.0582
1971	.1621	.1563	.1625	.1281	.0846	.0604	.0824	.0650
1972	.1648	.1582	.1668	.1313	.0878	.0629	.0866	.0677
1973	.1520	.1489	.1603	.1233	.0789	.0525	.0808	.0564
1974	.1552	.1592	.1780	.1352	.0837	.0529	.0885	.0567
1975	.1783	.1854	.2180	.1696	.1130	.0703	.1014	.0781
1976	.1957	.2066	.2430	.1908	.1280	.0803	.1111	.0894
1977	.1997	.2154	.2581	.2008	.1308	.0784	.1140	.0872
1978	.2072	.2277	.2713	.2089	.1339	.0776	.1184	.0863
1979	.2121	.2367	.2884	.2186	.1335	.0694	.1182	.0768

[1] 9-year economic life.
[2] 12-year economic life.

caused by the investment tax credit and the shorter tax lives.

The importance of the investment tax credit is evident when one compares the rental rates for unitary livestock facilities and multipurpose structures. The rental rates for unitary livestock facilities increased from 0.0582 in 1970 to 0.0604 in 1971, while the rental rate for multipurpose structures increased from 0.0582 to 0.0650. Prior to the reintroduction of the credit in 1971, unitary livestock facilities and multipurpose structures received identical tax treatment; they were assumed to have the same economic lives, and their prices were equal. The only parameter which differed among the categories was that unitary livestock facilities were now eligible for the 7-percent investment tax credit.

In 1974, a high inflation rate (12.2 percent) boosted rental rates for all categories dramatically. Higher inflation rates increased rental rates by reducing the real value of the tax depreciation deductions and the investment tax credit. Inflation also produces a bias between short- and long-lived assets. Inflation affects short-lived assets more because a larger percentage of depreciation deductions are claimed earlier in the asset's life, reducing its real values by a greater amount. For example, from 1974 to 1979, the rental rate for both tractor categories increased from 0.178 to 0.2884 and from

0.1352 to 0.2186, while the rental rate for long-lived equipment increased from 0.0837 to 0.1335.

Estimated rental rates are significantly higher under a no-tax scenario (table 6). This situation does not imply that the tax system has actually reduced rental rates. Instead, the no-tax scenario reflects the higher real return to equity (8 percent) and, because the interest expenses are no longer deductible, the higher real interest rates which were used to discount future returns.[12] Table 6 also shows which asset groups have benefited most from the tax system. Prior to 1962, rental rates for each asset category except tractors averaged about 2-3 percent higher under the no-tax scenario.

From 1961 to 1968, rental rates are significantly higher under the no-tax scenario for each category, with rental rates for long-lived farm equipment and crop storage structures showing the largest increase. This dramatic change is a result of shorter tax lives and the introduction of the investment tax credit in 1962. Although multipurpose structures and unitary livestock facilities were not eligible for the investment tax credit, their tax lives were reduced from 50 to 25 years. This reduction raised rental rates by 7 percent in 1962 under the no-tax

Table 6—Percentage change in implicit rental rates under a no-tax scenario, 1955-79

Year	Autos	Trucks	Tractors (9)[1]	Tractors (12)[2]	Long-lived farm equipment	Unitary livestock facilities	Crop storage structures	Multipurpose agricultural structures
					Percent			
1955	2.56	2.22	0.19	1.31	2.65	2.80	1.81	2.80
1956	2.05	1.73	−.57	.61	2.00	3.52	1.09	3.52
1957	2.14	1.69	−.62	.57	2.04	3.41	1.08	3.41
1958	2.81	2.41	.42	1.61	3.35	3.23	3.00	3.23
1959	2.91	2.47	.48	1.74	3.33	3.16	2.97	3.16
1960	2.98	2.51	.47	1.70	3.50	3.12	3.13	3.12
1961	3.03	2.64	.69	1.94	3.55	2.77	3.38	2.77
1962	9.54	9.08	7.61	8.91	12.04	7.32	14.07	7.32
1963	9.46	8.97	7.46	8.75	11.95	7.30	14.13	7.30
1964	11.22	10.80	9.29	10.56	13.73	7.04	15.96	7.04
1965	11.15	10.67	9.23	10.51	13.69	7.78	15.55	7.78
1966	10.69	10.26	8.85	10.11	13.43	8.43	15.47	8.43
1967	10.78	10.35	8.72	10.07	13.48	8.04	15.74	8.04
1968	10.44	9.91	8.16	9.71	13.27	8.65	15.65	8.65
1969	4.17	3.16	−.26	1.23	4.77	9.35	7.19	9.35
1970	4.39	3.32	−.12	1.38	5.01	6.87	7.35	6.87
1971	10.92	10.36	9.42	10.93	14.54	15.40	16.87	7.23
1972	10.86	10.43	9.41	10.89	14.35	15.58	16.74	7.39
1973	9.34	8.73	7.55	9.25	13.81	18.10	16.96	9.93
1974	8.57	7.98	6.74	8.65	13.50	20.98	17.18	12.87
1975	14.58	13.92	12.16	13.97	16.73	20.63	21.50	8.58
1976	15.18	14.62	12.92	14.62	18.91	19.55	21.60	7.38
1977	14.62	13.97	12.20	13.99	18.43	20.66	21.32	8.49
1978	13.98	13.18	11.13	13.12	18.22	21.52	21.71	9.27
1979	12.68	11.96	9.71	11.89	17.75	25.65	21.83	13.54

[1] 9-year economic life.
[2] 12-year economic life.

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[12] In a no-tax scenario, the appropriate rate of return to equity is a before-tax return. Therefore, I used an 8-percent real return to equity for the estimates in table 6 rather than the 6-percent real after-tax rate of return used for the rental rates presented in table 5.

scenario as opposed to a rise of only 3 percent in 1961. For autos, trucks, and tractors, tax lives were not reduced in 1962, but the investment tax credit caused 8-10 percent higher rental rates under the no-tax scenario. Long-lived farm equipment and crop storage structures benefited most from the 1962 tax changes. Tax lives for long-lived equipment were reduced from 15 to 10 years and from 25 to 10 years for crop storage structures. Both long-lived equipment and crop storage structures were eligible for the investment tax credit. Shorter tax lives and the investment tax credit boosted rental rates 12 and 14 percent, respectively, under the no-tax scenario for long-lived equipment and crop storage structures. These tax-induced advantages, measured in terms of rental rates, for equipment and crop storage structures continued through 1968. However, with the repeal of the credit in 1969 and 1970, the relative tax advantage shifted back toward unitary livestock facilities and multipurpose structures.

The investment tax credit was reintroduced in 1972, and unitary livestock facilities were added to the list of assets eligible to receive the credit. Tax lives for most assets were also reduced. As in 1962-68, the rental-rate advantage from 1971 to 1979 shifted back toward assets which were eligible for the credit. Assets such as crop storage structures, unitary livestock facilities, and long-lived equipment, which were eligible for both the credit and significantly reduced tax lives, benefited most under the tax system.

During 1955-79, Federal income tax policy greatly influenced rental rates among various farm assets. Although no one asset category benefited most in all years, specific tax incentives such as the investment tax credit have created incentives to purchase relatively greater amounts of certain assets (table 6). The investment tax credit with relatively short tax lives has dramatically changed rental rates; crop storage structures, unitary livestock facilities, and long-lived farm equipment have received the largest benefits.

Conclusions

The development of implicit rental rates for capital inputs is an important concept for understanding the effect of tax-induced changes on agricultural investment. Changes in tax laws may distort relative rental rates among various asset categories, increasing demand for assets which receive more favorable tax treatment and decreasing demand for assets which receive less favorable tax treatment. In the absence of other distortions, the resulting shift in investment decreases economic efficiency because the shift is a response to changes in tax laws rather than a response to market changes.

The results of this analysis are conditioned on the assumptions used to estimate the rental rates and the necessity to use proxy-type data because conceptually correct data do not exist. The implicit rental rates presented here are estimates of the true rental rates that would prevail under the given set of assumptions. These caveats notwithstanding, the weight of this analysis suggests that tax policy has indeed affected rental rates for farm equipment and structures, and, as demonstrated in the appendix, this conclusion holds over a range of assumptions about real rates of return and an alternative assumption about capacity depreciation.

More research is needed to determine the responsiveness of the food and fiber sector to changes in tax laws. Researchers need to incorporate implicit rental rates into a longrun dynamic optimization framework where short, intermediate, and longrun investment responses can be quantified. Given the fervor with which Federal income tax policy is employed as an incentive to spur investment, we need a broader understanding of how tax policy affects investment behavior.

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Appendix

I developed the implicit rental rates presented in appendix table 1 under the assumption of a "one-hoss shay" capacity depreciation pattern to test the sensitivity of the capacity depreciation assumption. The rental rates under the "one-hoss shay" depreciation pattern are significantly lower than those estimated under the double-declining balance method. For example, rental rates for automobiles ranged from 0.1408 to 0.2121 under the double-declining balance assumption whereas rental rates ranged from 0.0681 to 0.0945 under the "one-hoss shay" assumption. Although the "one-hoss shay" capacity depreciation assumption did affect the magnitude of the estimates, it did not significantly affect the ranking of the seven asset categories. Rental rates for autos, trucks, and tractors remained significantly higher than those for long-lived equipment and structures.

In addition to the capacity depreciation assumption, a second important assumption regarding the rental rates estimates is the required real after-tax return to equity. To test the sensitivity of this assumption, I also estimated rental rates for long-lived farm equipment with real after-tax returns to equity equal to 3 and 9 percent. Appendix table 2 shows the results of the alternative rates of return to equity. Rental rates estimated under a 3-percent real after-tax return to equity average about 10 percent lower than rental rates estimated under the 6-percent real after-tax return to equity assumption; rental rates estimated under the 9-percent assumption average about 10 percent higher than rental rates estimated under the 6-percent assumption.

Appendix table 1—Implicit rental rates for farm equipment and structures, 1955-79

Year	Autos	Trucks	Tractors (9)[1]	Tractors (12)[2]	Long-lived farm equipment	Unitary livestock facilities	Crop storage structures	Multipurpose agricultural structures
					Rate			
1955	0.0681	0.0565	0.0508	0.0405	0.0285	0.0239	0.0294	0.0239
1956	.0671	.0574	.0496	.0390	.0268	.0211	.0279	.0211
1957	.0712	.0616	.0531	.0418	.0288	.0221	.0287	.0221
1958	.0753	.0655	.0565	.0449	.0313	.0241	.0297	.0241
1959	.0781	.0683	.0593	.0473	.0332	.0249	.0303	.0249
1960	.0782	.0674	.0607	.0484	.0346	.0256	.0307	.0256
1961	.0788	.0681	.0626	.0501	.0359	.0269	.0318	.0269
1962	.0722	.0628	.0593	.0473	.0331	.0252	.0284	.0252
1963	.0710	.0617	.0596	.0475	.0332	.0250	.0285	.0250
1964	.0705	.0612	.0604	.0482	.0338	.0261	.0290	.0261
1965	.0689	.0608	.0606	.0482	.0337	.0257	.0292	.0257
1966	.0660	.0593	.0610	.0481	.0330	.0243	.0287	.0243
1967	.0675	.0613	.0637	.0504	.0349	.0265	.0308	.0265
1968	.0672	.0620	.0652	.0513	.0349	.0260	.0311	.0260
1969	.0712	.0671	.0733	.0574	.0385	.0280	.0367	.0280
1970	.0761	.0730	.0791	.0625	.0423	.0343	.0423	.0343
1971	.0784	.0753	.0778	.0619	.0425	.0369	.0438	.0397
1972	.0794	.0759	.0796	.0633	.0439	.0380	.0457	.0409
1973	.0697	.0683	.0736	.0565	.0365	.0271	.0387	.0291
1974	.0694	.0713	.0802	.0605	.0372	.0249	.0403	.0267
1975	.0838	.0869	.1020	.0797	.0535	.0390	.0507	.0433
1976	.0937	.0986	.1154	.0914	.0634	.0471	.0575	.0525
1977	.0938	.1010	.1207	.0943	.0628	.0432	.0567	.0480
1978	.0952	.1047	.1248	.0960	.0622	.0396	.0564	.0441
1979	.0945	.1057	.1295	.0974	.0590	.0315	.0529	.0348

[1] 9-year economic life.
[2] 12-year economic life.

Appendix table 2—Implicit rental rates for long-lived farm equipment under alternative real after-tax returns to equity, 1955-79

Year	$r_e = 0.03$	$r_e = 0.06$	$r_e = 0.09$
		Rate	
1955	0.0510	0.0567	0.0625
1956	.0494	.0551	.0610
1957	.0528	.0588	.0650
1958	.0566	.0627	.0691
1959	.0595	.0660	.0726
1960	.0619	.0685	.0753
1961	.0637	.0705	.0775
1962	.0593	.0656	.0721
1963	.0597	.0661	.0727
1964	.0605	.0670	.0737
1965	.0608	.0672	.0739
1966	.0604	.0670	.0738
1967	.0636	.0705	.0777
1968	.0644	.0716	.0790
1969	.0718	.0797	.0878
1970	.0776	.0859	.0945
1971	.0766	.0846	.0929
1972	.0793	.0878	.0965
1973	.0704	.0789	.0877
1974	.0743	.0837	.0935
1975	.0998	.1130	.1232
1976	.1153	.1280	.1411
1977	.1173	.1308	.1447
1978	.1194	.1339	.1491
1979	.1182	.1335	.1497

Beliefs of Farmers and Adoption of Integrated Pest Management

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Abstract

Georgia peanut farmers have adopted integrated pest management (IPM) on only a limited basis, although objective data indicate that IPM technology may be more efficient than conventional pest control strategies. Users and nonusers of IPM hold different views pertaining to the consequences of employing IPM. These beliefs influence its use. Educational programs on these beliefs should influence adoption and continued use of IPM. This article analyzes belief data pertaining to IPM among 192 Georgia peanut farmers and explores the relationship between beliefs about IPM and its adoption.

Keywords

Integrated pest management, risk, beliefs

Introduction

Integrated pest management (IPM) programs have recently expanded to encompass a multitude of crops. IPM programs are generally designed to optimally manage pest populations so that producers' profits are maintained or enhanced with minimal environmental degradation. Recent economic analysis indicates that peanut producers who employ a mean level of IPM have 34-percent higher profits and significantly lower insecticide expenditures compared with conventional pest control (*14*).[1] Despite this economic advantage, farmers have been relatively slow to adopt IPM; less than 40 percent of Georgia peanut acreage is currently under some type of IPM program (*9*). One popular explanation of this slow adoption rate is that response to risk impedes adoption of new practices (*5, 7, 27*). A previous study of IPM adoption in California investigated risk preferences and subjective probability distributions of IPM users and nonusers (*13*). The two groups indicated no differences in risk preferences, but each group perceived that its practice was the least risky.

This prominence of risk aversion in economic adoption literature reflects an attempt to explain behavior inconsistent with neoclassical microeconomics under certainty with an alternative economic theory. A potential weakness of this approach is that not all departures from neoclassical profit or utility maximization can be attributed to risk aversion (*25, 28*).

Risk aversion can be confused with behavior under certainty because of dynamic considerations (*3*), incomplete specification of resource constraints (*4*), dispersion of price expectations (*24*), and transactions costs for commodities which are periodically both inputs and outputs (*26*). Carlson recently concluded that risk aversion may not affect pest control decisions even though pest control does affect risk

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

(*6*). In a broader view, neither profit maximization nor risk aversion may be the most important goals in pest control. Economists often tend to use their theory to explain behavior motivated by goals and constraints outside the realm of economics. Dillon, a pioneer in risk analysis in agricultural economics, endorses this view in reference to the relationship between risk and economic development:

> Most people would agree that uncertainty prevails in underdeveloped agriculture and that development would be facilitated by an appreciation, understanding and recognition of this uncertainty. While not disagreeing with this assessment, my view, however, is that uncertainty is not a major detriment to agricultural development. It is far overshadowed by the influence of political goals, resource ownership, human capital stock, social power, tradition, and ignorance. Compared to these, uncertainty is just a marginal element in most less developed countries. We do best to recognize uncertainty, of course, but we delude ourselves if we think of it as a key factor to development except in countries where occasional crop failures on a grand national scale are not expected (*8*, p. 37).

Literature on goals of U.S. farmers also supports the existence of noneconomic goals (*23*). Thus, a study of the importance of economic goals in the adoption of IPM should also include other broader goals for comparison.

The purpose of this article is to present an interdisciplinary study of the relationship between risk and other perceptions of farmers and their adoption of IPM. Working with entomologists and psychologists, we identified potentially important economic and other consequences of decisions on pest control related to IPM. We represented these aspects as "belief measures," a psychological concept. We collected belief data on IPM, including a risk measure, for Georgia peanut producers in a 1982 telephone survey.

The Concept of Beliefs

Beliefs are defined as information one holds about a particular object and are different from a related term, attitudes. Attitudes are affective or emotional responses one has toward an object. For example, the statement "I do not like IPM" is an attitude; "IPM increases returns" is a belief. Although theoretical constructs are often difficult to reconcile among different disciplines, attitudes are similar to the economic concept of preferences, and beliefs are similar to the concept of expectations including subjective probability distributions (*20*). Belief measures have at least two advantages for this study. First, the concept is flexible enough to encompass both economic and other perceptions about IPM. Measurement of beliefs has extensive psychometric foundations and is not subject to the empirical problems of the conventional economic measures of risk preferences and subjective probability distributions.[2]

The psychological literature has two alternative theories concerning the relationship between beliefs and behavior. *Learning theory* espouses the view that beliefs underlie attitudes which, in turn, motivate a response or behavior (*12*). For example, the belief that IPM increases returns leads to a positive attitude towards IPM and eventual adoption. *Cognitive dissonance* is the second theory about the relationship between beliefs and behavior. A central proposition of this theory is that holding attitudes and beliefs inconsistent with current behavior is discomforting. These attitudes and beliefs are modified to become consistent with current behavior (*11*). Cognitive dissonance theory implies that beliefs may not explain use of IPM, but may instead reflect a rationalization of current behavior. Under this theory, differences in beliefs would not explain adoption.

Assuming that IPM is more profitable than are conventional control methods, users may have adopted IPM, under learning theory, because they gained information from educational materials or observations of other farmers, causing them to develop positive beliefs about IPM. However, farmers who have not adopted IPM have not developed these same positive beliefs because they lack access to or trust in the information about IPM. In contrast, cognitive dissonance would imply that these respective beliefs did not motivate adoption behavior, but arose *ex post facto* to rationalize behavior in a consistent manner.

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[2] Musser and Musser recently reviewed the literature on problems in eliciting risk preferences and probability distributions in relationship to psychological theories on risk decisions (*20*). The main empirical problems are instability of the measures at different times and lack of evidence on the relationship between these measures and behavior. Problems with these procedures are not surprising considering the current psychological evidence that individuals are poor intuitive statisticians. For example, individuals tend to overweight current or otherwise very salient outcomes over more distant outcomes, and they do not consider prior information such as suggested by Bayes Law. Furthermore, they overweight unlikely events and underweight more likely events. Agricultural economists have been aware of this literature for some time (*2*). However, they have not fully appreciated the implications of the literature on economic methodology. Kahneman and Tversky provide a recent introductory survey of some of this literature (*16*).

The learning approach is more consistent with the perspective of economic theory and the whole rationale of the agricultural land-grant system. Under this view, an investigation of beliefs among IPM users and farmers who practice conventional control methods may reveal differences in beliefs that could be used to design an educational program to modify beliefs and, therefore, to change behavior. In contrast, the cognitive dissonance approach suggests limited usefulness of an educational program to change behavior. Beliefs about and support for IPM would change after IPM was adopted. Adoption may require coercion through the political-legal system or some stronger economic incentives such as subsidies.

As with all theories, both theories are abstractions of human behavior, and both may operate at different times. For example, a positive belief may motivate behavior which in turn motivates a more positive belief towards the behavior. Alternatively, some beliefs about an object may motivate behavior towards that object, whereas other distinct beliefs may adjust rationalization to behavior. Given the considerable differential relevance of the two theories for public programs on IPM adoption, it is important to distinguish the process involved in the belief formation. Testing the alternative theories of IPM is unfortunately difficult in a cross-sectional study such as this article. Under the learning approach, IPM users should have more positive beliefs about the benefits of IPM than do nonusers, who practice conventional methods, because beliefs influence behavior. However, user and nonuser beliefs would adjust to the same pattern for rationalizing behavior under cognitive dissonance. Hanemann and Farnsworth recognize these alternative explanations of their cross-sectional study of IPM adoption (*13*). Standard methodology to measure beliefs does provide measures of support for various beliefs, which may provide some support for alternative theories. For example, positive beliefs about IPM among nonusers is inconsistent with cognitive dissonance.

Further dividing farmers into present users who are currently using IPM, past users who have discontinued use of IPM, and nonusers who have never used IPM may provide additional evidence for these alternative theories. The behavior of past users is an interesting issue. If IPM is, in fact, more profitable, then past users were not able to recognize this fact, ignored the information, or had inadequate management to implement IPM. Under learning theory, this process led to more negative beliefs and the reemergence of conventional methods; of course, these beliefs would adjust after the behavioral change under cognitive dissonance. However, cognitive dissonance implies that beliefs of past users would be in the interval between beliefs of present users and nonusers. Beliefs of past users would be more negative than beliefs of present users to rationalize their current behavior, but would still be more positive than beliefs of nonusers because of their need to rationalize past behavior. Under learning theory, a less clear prediction is possible. Past users discontinued IPM because the beliefs that motivated adoption became less positive; thus, their beliefs should be more negative than present users. Although the beliefs of past users may be as negative as those of nonusers, some may have more positive beliefs than nonusers, which could result in a similar pattern for these groups as does cognitive dissonance. However, a different pattern of beliefs could also hold under learning theory. The experience with IPM provided past users with more information about both alternatives, which causes their beliefs to become even more negative than nonusers. Thus, an intermediate positive for past users provides no evidence on the two theories, but the more negative beliefs of past users supports learning theory.

A complete testing of the alternative theories would require time series data on beliefs of each group. Under learning theory, beliefs of present users would be higher than those of nonusers before adoption, and beliefs of past users would be lower than those of present users before discontinuation. Under cognitive dissonance, these differences would not exist before behavior changes but would arise only after behavior change. Although such time series data were unavailable for this study, the number of years present users have used IPM was available and could provide some evidence on this relationship. As more time elapses, present users should develop a more positive attitude towards IPM under cognitive dissonance to rationalize continued use. A similar relationship could exist under the learning theory if IPM fulfilled expectations. However, the opposite pattern is also consistent with learning theory. Unfulfilled expectations would lower the initial level associated with adoption; if these beliefs decline to a certain point, present users would become past users. Thus, changes in belief among present users through time can reject the cognitive dissonance explanation if beliefs are inversely related to tenure, but these changes cannot definitively reject the learning explanation.

Even if the relationship between beliefs and adoption cannot be established, analyzing differences in beliefs among users and nonusers provides evidence on the importance of different dimensions of IPM programs for the different groups. Beliefs that are more strongly held, as measured by differences between the two groups, are relevant for farmers either in explaining or rationalizing behavior. For example, the differences in risk perceptions found in Hanemann and Farnsworth indicate that their sample is motivated by risk aversion (*13*). If no differences were found or if the reverse pattern held, the study would have supported the view that risk aversion is not important.

Data

This study on beliefs was part of a larger study which evaluated the IPM program sponsored by the Department of Extension Entomology of the Georgia Cooperative Extension Service. The most important component of the program involved periodic insect counts by scouts and treatment recommendations based on damage thresholds. Present, past, and nonparticipants in extension IPM were considered present users, past users, and nonusers, respectively, for our study, even though some farmers in Georgia practice IPM outside this program (*9*).

We obtained belief data on IPM for a stratified random sample of peanut producers in six Georgia counties selected from a list of Georgia peanut producers provided by the Georgia State Office of the U.S. Agricultural Stabilization and Conservation Service. From a sample of 240 producers, 192 (80 percent) cooperated in completing a telephone survey. The survey, developed by a team of entomologists, cooperative extension county agents, agricultural economists, and industrial psychologists, was conducted in late spring-early summer of 1982.

The survey required several months to devise. Each question was evaluated in terms of its contribution to obtaining the desired information on pest management practices. The questionnaire was pretested at several stages of development, with confusing or misleading questions being clarified or deleted. A copy of the final questionnaire is available in Edwards, Musser, and Wetzstein (*10*).

Nine students enrolled at the University of Georgia conducted the interviews. Prior to the interviews, the students were provided with an explanation of the questionnaire and its purpose, given appropriate standard answers to probable questions, practice, and feedback. Calls were occasionally monitored and appropriate feedback given. The students placed the telephone calls in the early evening from Sunday through Thursday. The questionnaire contained 46 questions and required slightly less than 30 minutes to complete.

Table 1 lists both the eight belief questions included on the questionnaire and variable names for reference. The belief questions focused on aspects of insect control as important in managerial decisions on IPM use. These questions must be interpreted within the context of the whole questionnaire where users of IPM were considered as participants in the extension scouting program and nonusers apply pesticides on a fixed schedule. "Damage" and "yield" are concerned with monetary costs of insect control, and "profit" is associated with overall profit from use of IPM. "Risk" reflects a safety-first concept of risk which is generally more intuitive than are more general measures like variance associated with expected utility theory (*21*). "Personnel" and "environmental" were aspects of the use of IPM programs not directly reflected in profit calculations, but they may be important in the managerial process. "Method" was included largely as a methodological check on communication with the producer because the belief corresponds with the actual use of IPM for peanuts in Georgia.

Table 1—Belief measures

Belief variable	Questions[1]
General statement	I'd like to ask for your opinions on pest control strategies. These questions will ask you whether you strongly agree, agree, disagree, or strongly disagree with them. There are no right or wrong answers; these are only your opinions.
Damage	The likelihood of insect damage is lessened with the use of scouts. Do you: SA A D SD
Expense	It is less expensive to pay scouts to monitor my fields than spraying on a predetermined schedule. Do you: SA A D SD
Personnel	Hiring my scouts on a personal basis rather than going through my county extension program best serves my needs. Do you: SA A D SD
Yield	Farmers can expect higher average yields by spraying on a predetermined schedule rather than using scouts. Do you: SA A D SD
Environmental	The use of insecticides poses a harmful environmental threat. Do you: SA A D SD
Method	In my county the most widely used method of pest control is spraying on a predetermined schedule. Do you: SA A D SD
Profit	Some people argue that IPM produces higher profits. Others strongly disagree. Do you: SA A D SD with the following statement? Conventional pest management strategies give farmers higher profits.
Risk	People disagree about the differences in yield produced by integrated pest management (IPM) vs. conventional pest management strategies. Some argue that IPM produces better average yield over a period of years. Others say the same for conventional methods. Do you: SA A D SD with the following statement? IPM reduces the chances of having extremely low-yielding years.

[1] In the questions, strongly agree, agree, disagree, and strongly disagree are coded as SA, A, D, and SD.

To facilitate telephone responses, interviewers gave respondents one of four choices when they answered the questions: (1) strongly agree, (2) agree, (3) disagree, and (4) strongly disagree. These responses were coded 4, 3, 2, and 1, respectively, for statistical analysis, and they were assumed to reflect measurements of continuous theoretical variables.

The assumption in the coding that these responses reflect equal intervals along an underlying scale is standard methodology in psychometrics (*1*). The questions were counterbalanced to preclude a response bias because "strongly agree" is the most positive response to IPM on all beliefs. "Strongly agree" is the most positive for the categories of damage, expense, environmental, and risk, whereas "strongly disagree" is the most positive for personnel, yield, and profits. Questions included in the survey concerned use of IPM in the current year and in past years. These questions were used to separate respondents into present user, past user, and nonuser groups. Data on tenure of the farmers in IPM were available for only four of the six counties, so analysis of possible changes in IPM beliefs through time were confined to a subset of the sample.

Results

We first applied a multivariable analysis of variance (MANOVA) to the eight belief variables. MANOVA tests the hypothesis of a common set of means for the eight variables in the three producer IPM groups (*19*). The MANOVA F test was significant at the 1-percent level; thus, the hypothesis of common means can be rejected. We then used analysis of variance (ANOVA) of each belief variable by IPM use group to determine which variables contributed to the MANOVA result. Table 2 summarizes the ANOVA results along with mean responses for each producer group.

The damage, expense, personnel, and yield variables were directly concerned with the use of insect scouts, which is the most important component of IPM programs in Georgia. The expense question had different responses among the groups significant at the 10-percent level, and the other three variables had differences significant at the 1-percent level.

Present users believed that scouting reduced insect damage, was less expensive, and resulted in higher yields. Although the beliefs of present users differ significantly from the other two groups, the mean response for all producers indicated that they either agreed or strongly agreed that scouting reduced damage and was less expensive. For the yield questions, present users disagreed that higher yields resulted from spraying on a predetermined schedule rather than from using scouts; mean values of the other two groups lay between disagree and agree.

Table 2—IPM belief results, by user group

Belief	Mean value			ANOVA F statistic	Significance level[1]
	Present user	Past user	Nonuser		
Damage[2]	3.23	3.08	2.93	6.98	0.0012***
Expense[2]	3.39	3.23	3.06	2.66	.0727*
Personnel[3]	2.42	2.73	3.30	5.14	.0067***
Yield[3]	1.95	2.65	2.43	5.85	.0035***
Environmental[2]	2.31	2.50	2.72	1.85	.1607
Method[4]	2.60	2.73	2.72	.23	.7936
Profit[3]	2.22	2.62	2.72	6.16	.0026***
Risk[2]	3.07	3.77	3.54	3.27	.0404**
Number of producers	106	26	54	NA	NA

NA = Not applicable.

[1] * = Significant at the 10-percent level;
** = Significant at the 5-percent level; and
*** = Significant at the 1-percent level.

[2] Large number indicates positive belief about IPM.

[3] Small number indicates positive belief about IPM.

[4] This variable is a methodological check on communication with the producer. The magnitude of the number indicates no level of belief about IPM.

Thus, the effect of insect control on yields seemed to indicate more important differences than did the components measured by these other three variables.

The profit question also produced differences among the groups significant at the 1-percent level with group patterns similar to the yield question. Users disagreed that conventional pest management strategies give farmers higher profits, whereas past and nonusers generally tended to agree more with this statement. The mean responses to expense, yield, and profit questions indicate that the differences in beliefs on profits associated with IPM use arose from differences in yields and revenues rather than costs. These beliefs only partially correspond with economic analysis of IPM use by Georgia peanut farmers. In their study of IPM use in Georgia peanut production, Hatcher, Wetzstein, and Douce found a significant reduction in insecticide cost, which corresponded to beliefs of all groups, and a significant increase in yields, which is consistent only with the beliefs of users (*14*).

For the risk question, all groups tend to agree that IPM reduces the chances of having extremely low-yielding years. In fact, past users and nonusers generally believe more strongly that IPM reduces variability. Differences between these groups were significant at the 5-percent level. These results sharply contrast with the previous findings of Hanemann and Farnsworth (*13*). Because belief measurement has fewer methodological problems than does elicitation of subjective probabilities, the findings of this article are credible. If the risk responses are interpreted jointly with the profit responses for each group in isolation, they seem plausible with expected utility theory. Users adopt IPM because they believe it raises average profits and lowers risk, whereas the other group does not adopt IPM because the sacrifices in expected profits does not compensate for the decreased risk. However, the pattern of risk responses among the groups is difficult to rationalize. Assuming producers are risk averse, the risk responses are definitely inconsistent with cognitive dissonance; users have a less positive view than do the other two groups. Although these beliefs might be consistent with learning, they do not explain the behavior. Profits alone explain behavior as well as profit and risk, suggesting that risk is not important in explaining the use of IPM.

If one relaxes the assumption of risk aversion, responses to the risk question are consistent with farmers' being risk seekers. Under this assumption, the low value for present users' risk response would be a positive belief in IPM, the higher value for nonusers' risk respond would be a negative belief, and the even higher value for past users' risk response would be a negative belief arising from learning behavior. As Young notes, past studies measuring risk preferences found some farmers' being risk seekers (*28*). However, the complete sample would probably not be dominated by risk-preferring behavior. Furthermore, the interest in risk in the adoption literature is motivated by an assumption of risk aversion; that is, risk seekers would readily adopt new technology perceived as being risky. This assumption does not seem a plausible method of interpreting risk. The results support the general view emerging in the literature reviewed in the introduction to this article—namely, risk is not important in the IPM adoption decision.

The method and environmental questions did not significantly differ among the groups. The mean responses to the method question were similar and indicated a tendency to agree. These responses indicated that producers had some knowledge of current pest control methods and that respondents were serious in their responses to at least this survey question. All groups had mean responses to the environmental question that were neutral; the mean responses had as much difference as some of the other variables, but had high variances as reflected in the F statistic.

Mean responses for past users were within the interval between present users and nonusers for most variables. Exceptions were the yield and risk questions. Past users tended to agree that higher yields resulted from spraying on a predetermined schedule rather than from using scouts, with a mean response of 2.65 compared with 2.43 for nonusers and 1.95 for present users. Past users strongly agreed with a mean response of 3.77, compared with 3.07 for present users and 3.54 for nonusers, that IPM reduces the chances of having extremely low-yielding years. Thus, past users believe that not practicing IPM will boost average yields and promote greater yield variability than do the other groups. The response on risk is again not consistent with their status as past users under either learning or cognitive dissonance. The yield response contradicts cognitive dissonance and suggests that experience with low yields contributed to past users' abandonment of IPM. Their management ability may have precluded implementing IPM practices, and their belief may have reflected this experience. This belief may have resulted from spurious correlation; the series of recent droughts in Georgia was probably the main reason for lower yields. Good extension information may have precluded formation of and action on this belief.

Besides responses from past users on yield and risk, overall responses to some variables also support learning theory. The nonusers' mean response of 3.54 on risk does not suggest reduction of cognitive dissonance. Similarly, nonusers' mean response of 2.93 on the damage question and 3.06 on the expense question indicates that they agreed with positive statements about IPM which is inconsistent with their behavior. The mean response of 2.42 on the personnel question for present users is also not consistent with current behavior. Finally, the largely neutral mean responses with large variances to the environmental question are inconsistent with cognitive dissonance; more consistent tendencies on this belief could have been a rationalization for behavior unrelated to profits of the business. No evidence on profit, which does have large differences among groups, is available, unfortunately.

We used linear regression analysis of beliefs of the present user groups to provide further evidence on the relationship between beliefs and behavior. We regressed the eight belief measures separately on the number of years a present user had participated in IPM. Data were available for 52 IPM users in four counties in 1979-82. We included county dummy variables in the regression analysis to account for possible differences in climatic and soil conditions. Table 3 gives the regression results. As previously discussed, a negative coefficient on years of IPM use is inconsistent with cognitive dissonance where "strongly agree" indicates a positive belief about IPM, and vice versa.

The regression analysis was not highly satisfactory. The R^2's were extremely low, even for cross-sectional regressions. None of the county dummy variables differed significantly from zero, indicating no geographical differences in beliefs between these three counties and the county with no dummy variable. Years of IPM use was significant at the 5-percent level in the damage equation. This negative coefficient indicated that the belief that the likelihood of insect damage is lessened with the use of scouts declined through time for users, which was inconsistent with cognitive dissonance. The coefficient on years of IPM use did not differ significantly from zero in the other equations. Furthermore, the signs of these coefficients do not prove the alternative theories in most cases.

Conclusions

Results support the view from earlier research that IPM users and nonusers hold different views about the consequences of IPM use. As expected, users of IPM hold more positive beliefs about IPM than nonusers, except one. The single exception concerned risk which, contrary to earlier research, had a reverse pattern. Because no theoretical explanation exists for the response pattern obtained on the risk question, these results suggest that beliefs about risk are not related to adoption of IPM. However, beliefs on average yields probably influence adoption and continued use of IPM. Although no direct evidence existed that beliefs on average profits influenced adoption of IPM, the predominance of evidence against cognitive dissonance processes for the other beliefs supports the view that the differences in beliefs on average profits also affect adoption. Thus, the results support the emerging trend in agricultural economics literature that profit maximization may explain much economic behavior formerly attributed to risk aversion. More research on this issue in reference to IPM seems warranted.

Results in tables 2 and 3 also support the view that beliefs about IPM influence adoption rather than reflect a cognitive dissonance response. Under this view, processing information correctly may influence beliefs and, therefore, adoption. These results directly affect the Cooperative Extension Service's National IPM Impact Study, which was designed to evaluate IPM programs in various States. This impact study outlines in detail the possible advantages of IPM over conventional practices. Our study indicates that the National IPM Impact Study can positively influence producers' adoption of IPM.

The psychological literature also suggests some methods to influence incorrect beliefs. Hovland,

Table 3—Regression results for belief and years of use for present users[1]

Belief measure	Intercept	Years of IPM use	County dummies			R^2
			1	2	3	
Damage[2]	4.00** (14.16)	–0.19* (–2.44)	0.23 (1.16)	0.06 (.27)	0.11 (.50)	0.16
Expense[2]	3.25** (11.42)	.06 (.70)	.15 (.72)	.18 (– .79)	.40 (1.74)	.12
Personnel[3]	2.29** (3.98)	– .04 (– .26)	– .29 (– .71)	– .13 (– .30)	.52 (1.12)	.08
Yield[3]	1.81** (3.28)	(– .05) (– .31)	.58 (1.47)	.54 (1.23)	.02 (.04)	.07
Environmental[2]	2.26** (5.73)	– .05 (– .42)	– .50 (–1.50)	.17 (.46)	.52 (–1.38)	.11
Method[4]	3.45* (4.94)	– .23 (–1.20)	5.97 (.00)	.04 (.06)	– .82 (–1.46)	.08
Profit[3]	2.69* (7.16)	– .06 (– .61)	.19 (– .70)	– .004 (– .01)	– .42 (–1.38)	.05
Risk[2]	1.96** (2.84)	.23 (1.21)	.15 (.30)	.28 (.50)	1.10 (1.98)	.11

NA = Not applicable.
** = Significant at the 1-percent level.
* = Significant at the 5-percent level.
[1] t-values appear in parentheses.
[2] Large number indicates positive belief about IPM.
[3] Small number indicates positive belief about IPM.
[4] This variable is a methodological check on communication with the producer. The magnitude of the number indicates no level of belief about IPM.

Janis, and Kelley suggest that correct information that is different from original beliefs must be provided in a way that incentives for change are provided (*15*). Such incentives might be a change in either the content of a message about the belief object or a perception about the expertise or prestige of the communicator. The recent emphasis on IPM evaluation by agricultural economists could provide these new incentives. Profit is probably a stronger motivator for farmers than are insect damage or environmental concerns about insecticide use. Furthermore, the perceived expertise of agricultural economists is important in reinforcing the expertise of entomologists involved in IPM programs.

Assessing IPM beliefs would be helpful in identifying incorrect beliefs of nonusers so as to develop educational programs which could change behavior. Furthermore, such an assessment might document the importance of both entomologists and agricultural economists in the evaluation and education program. Data in table 2 demonstrate these propositions. Beliefs of nonusers can be modified by evidence that field scouting tends to decrease crop damage and pesticide expenditures and to increase yield and net returns, both areas of entomological and economic expertise. Changing these beliefs may help encourage adoption. Information about the effect of IPM on average yields may renew the interest of past users in IPM. Finally, reinforcing beliefs of present users with information about the consequences of IPM is important to maintaining IPM use. We should place particular effort on developing and disseminating information about differences in yield and profits, the two beliefs about which significant disagreement existed between users and other groups.

Use of psychometric methodology to understand farm management decisions has potential in other areas beyond IPM programs. Psychological methodology has had limited use in agricultural economic research on farm firm decisions. Krause and Williams (*18*), and recent work by Klieberstein and others (*17*) and by Patrick, Blake, and Whitaker (*22*), on modeling multiple goals are exceptions. However, many adoption problems in agricultural production are similar to the IPM issue we discuss here. Adopting new technologies to facilitate agricultural development, which was the concern of much of the risk literature we reviewed in the introduction, is an obvious extension. Several issues of public concern in farm management may also be amenable to similar research; soil conservation, water conservation, and marketing strategies are several examples. Assessment of beliefs about adoption establishes the relevance of different forms of economic information in planning research and extension programs.

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Public Policy and the Reemergence of International Economic Influences on U.S. Agriculture

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Abstract

Recent literature on agricultural policy argues that a new market environment has emerged in the past 15 years characterized by the growing importance of international trade, a U.S. agricultural sector increasingly integrated into the U.S. and world macroeconomy, and an increasing price variability for agricultural commodities. A historical examination of the effects of trade, macroeconomic factors, and price variability on U.S. agriculture, however, shows that these influences are not new. Changes in agricultural and macroeconomic policies in the seventies have caused these characteristics to reemerge, albeit in a somewhat different form and magnitude than in previous decades.

Keywords

Agricultural policy, agricultural trade, macroeconomic influences, price variability

Introduction

Current literature on agricultural trade characterizes the international environment facing U.S. agriculture with three generalizations: (1) that trade plays an increasing role in U.S. agriculture; (2) that U.S. agriculture is increasingly integrated into the U.S. and world macroeconomy; and (3) that price variability for agricultural commodities is increasing (see Duncan and Borowski (*8*) for one example).[1]

These generalizations imply that international trade was not, until recently, very important to U.S. farmers and that the agricultural sector was largely isolated from the rest of the economy. Furthermore, the last statement implies that price variability due to the reliance on exports is a new problem for the sector. Economists have used these generalizations to argue in favor of a new U.S. policy to deal with this international environment.

A longer perspective, however, shows that these influences are not new, although the magnitude of these influences and the manner in which they affect agriculture may have changed. Except for two or three decades in the middle of this century, international trade has been critical to the well-being of the agricultural sector, agriculture has been sensitive to developments (shocks) elsewhere in the economy, and prices for farm outputs have been highly variable. The theme of this article is that changes in public agricultural and macroeconomic policy during the seventies allowed these elements to reemerge, albeit in a somewhat different form and magnitude than in previous decades.

Formation of future policies requires an understanding of how U.S. policy and the international environment have interacted in the past. In this article, we will broadly compare and contrast the international environment facing U.S. agriculture. We will separate influences which have reemerged from those we believe have changed. We will then attempt to link the role of trade and the variability in prices to the policy behavior of the U.S. Government.

We will identify four distinct periods of U.S. policy responses to the international environment. The first period, up to 1930, was a period of indirect Government intervention in agricultural commodity markets and of limited intervention in the macroeconomy. The period was characterized by an important role for trade, variable agricultural prices, and strong agricultural linkages to the macroeconomy.

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

During the next period, 1930-70, the U.S. Government assumed a major direct role in agricultural commodity markets and the macroeconomy. Trade's importance to U.S. agriculture was relatively small compared with domestic demand, price variability was reduced, and macroeconomic policy concentrated on aggregate demand management.

In the third period, 1970-80, changes in U.S. Government agricultural and macroeconomic policy allowed the international environment which faced U.S. agriculture in the past to reemerge. Agricultural commodity programs changed from price support using nonrecourse loans to income support via deficiency payments. Macroeconomic policy during this period became more chaotic and less able to manage aggregate demand.

In the last period, 1980 to the present, agricultural policy has shifted as policymakers attempt to operate in this reemerged environment. A critical policy issue is the type of public intervention strategy the United States should elect.

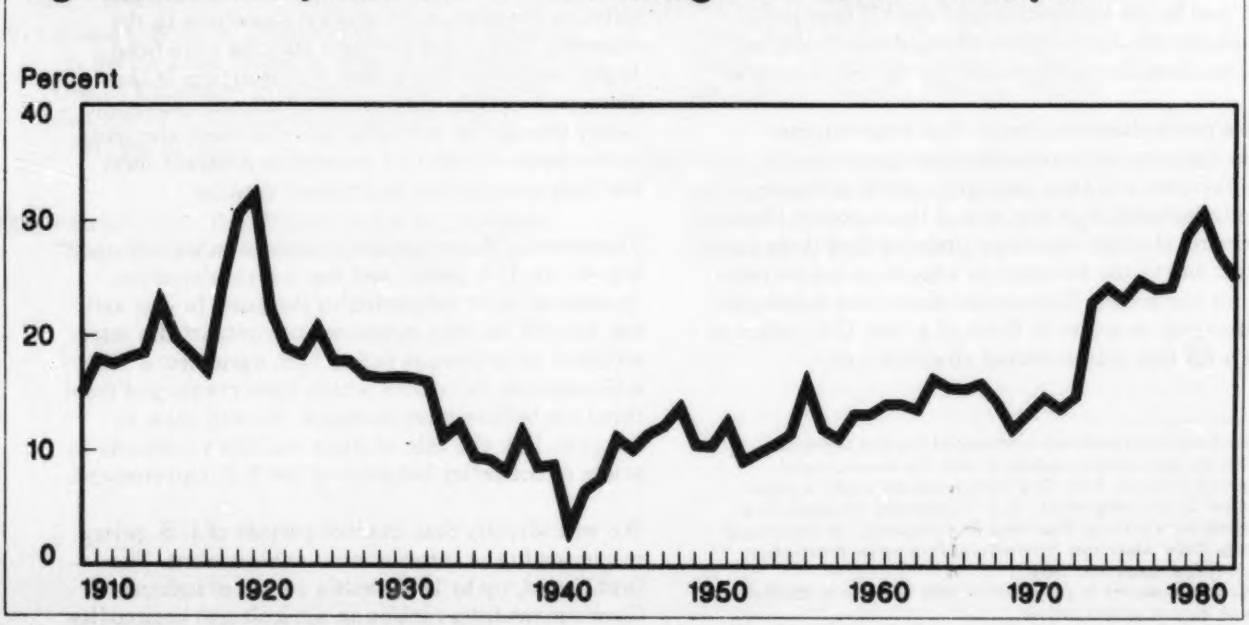
The longer run perspective discussed in this article shows that the United States had confronted these issues before and adopted two contrasting means of reacting to this international environment. One policy allows the domestic market to adjust to changing world market conditions, whereas the other prevents such adjustment through public intervention. Consideration of the historical experience of each policy strategy should provide insights into the direction of future policies.

Role of Trade

Except for a few decades of this century, trade has been critical to U.S. agriculture. It has been an important outlet for production and has been a source of instability for agricultural prices. Figure 1 shows that it was not until the seventies that agricultural exports as a percentage of farm cash receipts regained the levels obtained during the 1910-29 period (*6*). Tobacco was a major export since the early

Figure 1

Agricultural Exports as a Percentage of Cash Receipts



settlers arrived. With the invention of the cotton gin in 1793, cotton became a major export; in 1860, cotton constituted almost two-thirds of the total export trade of the United States (*18*). Historians argue that one of the major causes of the Civil War was the conflict between the agricultural export-oriented South and the manufacturing protectionist North. One author describes the situation in agriculture as: "During and after the Civil War the fluctuations of the currency and the high tariff worked especial hardship on the farmers as producers of staples which must be sold abroad. . ." (*3*, p. 20). Although this situation applied primarily to southern cotton and tobacco farmers, it was of growing importance to northern wheat producers as well. This quotation illustrates three concerns which sound familiar today: (1) currency fluctuations (inflation and exchange rates) (2) high U.S. tariffs (on nonagricultural goods) and (3) importance of export markets. The period following the Civil War was one of agricultural expansion, increased communication, and improved transportation, all of which encouraged international trade (*7*). The arrival of North American grain on European markets in the late 1870's was partially responsible for reconciling industrialists and agricultural interests in Germany, leading to Germany's tariff of July 1879 (*9*, p. 297). The recession which hit agriculture in 1921 was both the result of a decline in exports following World War I as European nations recovered from the war as well as the result of overexpansion in U.S. agricultural production to wartime needs.

Table 1 shows the average share of production exported for current major U.S. agricultural exports by decade since 1870 on a volume basis. The pattern is generally U-shaped. Prior to the thirties, trade was important for wheat, cotton, tobacco, and rice (*7*). The trough in the thirties reflects the tariff wars during the Depression, whereas the low values for the forties reflect the interruption of commerce during World War II. During the postwar period, the role of trade began to rise.

Wheat exports in the 1870-1929 period averaged 26 percent of production. During the thirties that share fell dramatically to 8.4 percent. Only after the passage of export subsidies and export promotion programs during the fifties did the export share of wheat production recover. The export share of wheat production rose to a peak of 58.1 percent in the seventies, but it fell slightly in the early eighties. Similar patterns over time are evident for corn and cotton, despite the fact that most of the corn was used onfarm wheras the cotton was marketed. Corn exports in the fifties were about the same share of production as during the 1870's. Corn exports in recent years have risen to 24 percent of production, about the same share wheat exports had in the 1870's. Although cotton exports as a share of production have risen, exports are still well below

Table 1—Average share of U.S. production exported for selected crops, by decade, since 1870

Decade	Wheat	Cotton	Tobacco	Corn	Soybeans	Rice
			Percent			
1870-79	25.4	64.7	59.1	4.4	[1]	[2]
1880-89	26.9	65.6	45.3	3.1	[1]	[2]
1890-99	30.1	68.6	37.3	5.3	[1]	[2]
1900-09	22.0	67.1	35.4	2.8	[1]	[2]
1910-19	23.5	57.6	37.0	1.8	[1]	16.5
1920-29	26.0	57.5	38.8	1.3	[1]	26.0
1930-39	8.4	50.9	31.4	1.6	6.7[3]	16.6
1940-49	18.7	23.1	22.4	2.0	2.8	42.7
1950-59	35.9	35.7	23.6	4.5	16.3	49.6
1960-69	53.6	35.0	26.1	12.4	28.1	61.2
1970-79	58.1	41.2	36.7	24.4	38.3	58.9

[1] Soybean production and trade data not reported prior to 1931.
[2] Rice production and trade data not reported prior to 1910.
[3] Nine-year average used.
Source: (*18*).

the contribution made in earlier periods. Tobacco exports were well below historical levels. Trade has become increasingly important to soybeans and rice.

Depending on when the comparison is made and what crop is considered, one can view the current large share of production exported as either a fundamental change or a reemergence of what existed before the thirties. For wheat, export trade was always important, but its contribution has risen. Trade is clearly more important for corn, soybeans, and rice. Exports for cotton and tobacco are less important than they were 50 or 100 years ago.

The figures do suggest some major changes during the intervening years. Foremost, the mixture of crops exported has changed. Wheat, cotton, and tobacco have given way to corn and soybeans. Unlike the pre-Depression years, the emphasis of U.S. export trade is more toward ingredients for livestock feed. Because meat demand tends to be more sensitive to income changes than is the demand for the wheat, rice, cotton, and tobacco, U.S. trade may be more sensitive to changes in income growth than in the past. Another fundamental change suggested by table 1 and figure 1 is that the role of exports in the aggregate has strengthened.[2] The domestic share has declined because over time the income elasticity for these crops in the United States has fallen because of high per capita incomes. Thus, current growth in U.S. domestic demand for most crops is largely due to population increases rather than to income changes (*4*).

The data presented in table 1 do disguise one change which is truly fundamental to understanding the present international environment facing U.S. agriculture. During the 1909-12 period, the export market for U.S. agricultural commodities was in Western Europe. When that market collapsed after World War I, U.S. agriculture collapsed as well. In 1909-12, 83 percent of U.S. exports went to Europe (excluding Russia), of which most was for the United Kingdom (*20*). Seventy years later, only 28 percent went to Western Europe, whereas 13 percent went to centrally planned nations and 36 percent went to developing nations (*19*). The shift in world trade patterns from Europe and toward centrally planned and developing nations represents a fundamental change. These nations' demand for food tends to be more income elastic than does Western Europe's; hence, developing nations' imports are more sensitive to changes in consumer expenditures. Most of these nations have borrowed heavily in international financial markets to finance imports. Their ability to sustain large food imports is now suspect as debt-servicing problems mount. These nations tend to rely on state trading institutions or more rigid import restrictions rather than on private markets. Thus, the institutional structure of the market has changed as trade patterns have shifted.

Variability in U.S. agricultural prices due to the integration in world markets is a problem currently facing U.S. agriculture. Except for the middle of this century, variability has always been an issue (*3*). In the early 19th century, increases in export demand for cotton raised prices and stimulated a western migration of the U.S. cotton industry (*12*). When supply increases outstripped demand, prices fell, land sales slowed, and producers switched to other crops. Such cycles have been frequent for cotton and other crops throughout the 19th and 20th centuries. A similar cycle began in 1972. High commodity prices and an expansionary monetary policy stimulated production and raised land values. Supply has recently outstripped demand, and commodity and land prices have fallen dramatically.

Table 2 shows the average percentage of year-to-year variations in U.S. season-average prices by decade since 1870, revealing a U-shaped pattern as with table 1. Prior to the thirties, prices were unstable. For wheat, the average percentage change in prices varied from a high of 26 percent in 1920-29 to a low of 13 percent in 1900-19. Corn prices also varied greatly, but did not have the range of variability which wheat prices had, from a low of 15.6 percent to a high of 22.6 percent. The average percentage changes in prices of cotton and tobacco were quite erratic prior to 1930, with lows of 5 percent and 6 percent and highs of 24.9 percent and 20.6 percent, respectively.

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[2] Weighting the proportion of each crop exported by its contribution to total production shows that corn dominates. Because exports are increasingly important to corn producers, the aggregate role of trade for U.S. crop producers has become increasingly more important.

Table 2—Average year-to-year changes in season-average prices received by U.S. farmers for selected crops, by decade, 1870-1979[1]

Decade	Wheat	Corn	Cotton	Tobacco	Rice
	Percent				
1870-79	13.64	20.20	13.34[2]	22.43	—
1880-89	20.60	22.56	5.14	15.70	—
1890-99	15.51	18.30	19.86	13.64	—
1900-09	13.06	19.29	19.26	6.13	—
1910-19	13.07	15.60	24.86	20.65	19.69
1920-29	26.05	17.63	18.01	10.34	13.20
1930-39	24.45	36.94	20.95	23.15	19.60
1940-49	14.90	23.16	12.81	10.73	16.84
1950-59	3.60	6.32	6.20	3.27	8.25
1960-69	11.76	6.17	9.99	4.01	2.00
1970-79	23.84	19.50	16.99	8.56	27.92

— = Not available.

[1] Calculated by averaging the absolute year-to-year price changes and dividing by the mean price for the decade.

[2] Data for 1876-79 only.

Source: (*18*).

During the thirties, year-to-year price changes were large—for corn the largest of the entire series and for wheat the second largest—because of large declines in crop prices during the Depression. In the fifties and sixties, the variation in prices for all commodities declined sharply. In the seventies, price variability resembled that of the twenties and thirties. The year-to-year price variability for wheat rose to 23.8 percent, just slightly above the "normal" level prior to 1930, but well within the overall historical range. The year-to-year changes for corn and cotton prices are consistent with the pre-1930 level, although the price of tobacco varied less. Only rice prices varied considerably above the pre-1930 level.

Although price variability itself is not new, the data in table 2 show that it has increased for all crops since the fifties and sixties. A major factor has been increased world agricultural trade barriers as well as changed policy instruments used for protection purposes. The growing importance of developing and centrally planned nations as markets for agricultural products has increased price variability. Most of these countries are state traders or they use other policies which sever the link between domestic and world prices (*1, 22*). An abrupt change in policy, such as the Soviet decision to import grain rather than slaughter livestock in 1972, can cause tremendous price changes in a world market where trade barriers allow relatively little adjustment to world price movements.

Although West European nations account for a declining share of world agricultural trade, particularly for wheat, they are still important factors in the market. At the outset of this century, the European nations primarily used tariffs to protect their agricultural producers (*11*). Tariffs permit price variations to move across borders (*1*). These nations have adopted policies in recent years which insulate their domestic markets from world price changes, thereby magnifying the instability in world prices.

Britain is a particularly useful example of such policy changes. In the early 20th century, Britain was a large wheat importer and followed a free trade policy. During the thirties, Britain adopted import tariffs as did all other countries (*11*). In 1973, Britain joined the EC and accepted the EC policy of variable levies which add to world price instability. Other European nations followed a similar path, although at different speeds. Current policies in Western Europe magnify the instability in world prices.

Institutional developments in other exporting countries may have also increased world price variability. The Canadian Wheat Board is a product of the Depression and acts to stabilize producer returns. The Australian Wheat Board is an outgrowth of World War II (*2*). Stochastic simulation analysis of board marketing suggests that these types of institutions can also increase world price variability (*14*).

Macroeconomics and U.S. Agriculture

Another recurring theme in the current literature is that U.S. agriculture is increasingly integrated into the U.S. and global macroeconomy. Except for the middle of this century, U.S. agriculture has been integrated into the rest of the economy. In the late 19th century, farmers' concerns focused on railroad shipping charges, credit, tariffs, and the U.S. currency. The populist platform of July 1892 advocated the free coinage of silver and a graduated income tax (7, p. 525). Other political demands by farmers included reduced tariffs on industrial goods and reduced interest rates, from 10 percent to 8 percent (*3*, pp. 120-22). The "boom and bust" cycles of the 19th and 20th centuries were heavily influenced by changes in the money supply. A policy to inflate the economy to benefit agriculture even helped launch William Jennings Bryan's 1896 presidential campaign. Agriculture versus protection debates are not a recent phenomenon. Conflicts between farmers seeking export markets and manufacturers seeking import relief were a major theme of U.S. history in the 19th century.

These same problems are faced today. The 1984 *Economic Report of the President*, for example, discusses the sensitivity of agriculture to changes in interest rates and monetary policy (*6*). According to *The Washington Post*, farmer representatives and labor leaders have exchanged sharp debate in hearings over auto-content legislation and restrictions on steel imports (*21*). U.S.-Chinese agricultural trade has been disrupted by disputes over protection of U.S. textile manufacturers.

If macroeconomic factors are not new to U.S. agriculture, why is it popular to write that they are? The statement that U.S. agriculture is increasingly integrated into the rest of the economy partly reflects an exceptional period for U.S. agriculture and partly reflects changes in the magnitude of interaction.

Although 19th century growth in U.S. agriculture and railroads was heavily financed by eastern U.S. and British banks and although farmers then purchased their inputs from the nonfarm sector and relied on credit, agriculture now depends even more on the rest of the economy than in the past. Table 3 shows the share of production costs and the share of interest on farm mortgage debt in U.S. gross farm income by decade since 1910. Both have the familiar U shape. In the 1910-19 period, 3.1 percent of farm income went to interest on farm mortgage debt. Declines in farm income during the twenties and thirties increased the share to almost 5 percent. By the forties, the interest share had fallen to 1 percent, perhaps a reaction to the use of debt financing by those farmers who survived the Depression. Interest as a share of gross receipts began to rise in the sixties and was only slightly greater in the seventies than in the 1910-19 period.

Table 3—Shares of interest on farm mortgage debt and production expenses in U.S. gross farm income, by decade, 1910-79

Decade	Share of farm income	
	Interest[1]	Production expenses[2]
	Percent	
1910-19	3.1	48.9
1920-29	4.8	57.7
1930-39	4.6	58.6
1940-49	1.0	50.8
1950-59	1.1	64.3
1960-69	2.3	69.4
1970-79	3.5	69.0

[1] Interest on farm mortgage debt divided by gross farm income.

[2] Total production expenses divided by gross farm income, including feed purchased, livestock purchased, seed purchased, fertilizer and lime, repairs, depreciation, hired labor, taxes on farm property, interest on farm mortgage debt, and rent to landlord.

Source: (*18*).

The share of farm income going to all production expenses tells a slightly different story. Prior to the Depression, inputs purchased accounted for between 48.9 and 58.6 percent of gross farm income. During the fifties, sixties, and seventies, the inputs' share of farm income rose to 64.3 percent, 69.4 percent, and 69 percent, respectively (table 3). One major development was that after World War II, U.S. agriculture increased its reliance on purchased fertilizer, seed, and fuel.

Flexible exchange rates and international asset markets represent other factors which may have reemerged in a different form. With the currency-flow system, international currency transfers, in principle, served to expand or to contract the monetary base, thereby causing internal price adjustments to external disequilibrium. With the end of the Bretton Woods Agreement in the early seventies, exchange rate movements caused internal prices to adjust to external disequilbrium unless other policies were used to prevent this adjustment. Schuh argues that the emergence of world financial asset markets in the context of flexible exchange rates is a fundamental change (*17*). Whether this situation represents a change can be debated. European and U.S. asset markets were well integrated in the 19th century as extensive foreign (mostly European) financing of U.S. agricultural development showed. Given the importance of Europe to

U.S. exports in the early 20th century, the export market and financial asset market may have been as completely integrated then as it is now.

World trade patterns have fundamentally changed as developing and centrally planned countries have increased their importance to world agricultural trade. World financial asset markets have expanded to meet this change. The ability of these nations to finance imports of agricultural products, or to increase expenditures in relation to income, is a critical development. The pool of loanable funds worldwide expanded rapidly after the oil price rises in 1973 and 1979. The use of monetary policies to accommodate these price shocks, especially after 1973, allowed financial assets to flow from developed countries to oil exporters, who then (through commercial banks) provided credit to developing and centrally planned nations. The rapid growth in demand for U.S. agricultural exports in the late seventies was partly due to growth in exports to developing and centrally planned countries resulting from these financial transfers. U.S. agricultural exports slowed in the early eighties because these nations were unable to service their debts which had accrued as a result of these transfers. A major difference with the past is that the loans of the late seventies were made to national governments rather than to individuals. As a result, bank solvency and in some cases the solvency of the world financial system depend on a single debtor's ability and willingness to repay obligations.

Reemergence of the International Environment

The changes in the international trade environment facing U.S. agriculture represent a reemergence of the old environment with a somewhat greater influence on U.S. agriculture. Why did the old environment reappear? Changes in U.S. commodity policies and in U.S. macroeconomic policy appear to be strongly linked with this reemergence.

The U-shaped patterns observed earlier reflect changes in these factors. The data can be divided into four phases based on U.S. Government policy. The first phase was one of limited direct U.S. Government involvement in both agricultural commodity markets and the macroeconomy; that phase ended about 1930. Prior to that time, the direct involvement of the Federal Government in agricultural commodity markets was limited. The Homestead Act, the Morrill Land Grant Act, and the establishment of the U.S. Department of Agriculture and the Extension Service were aimed primarily at improved production and land availability rather than at price support. The Federal Land Bank system, established in 1916, provided long-term credit, while Federal Intermediate Credit Banks were established in 1923 (*4*). These policies were forms of production subsidies. The Agricultural Marketing Act of 1929 created the short-lived Federal Farm Board, but not until 1933 did the U.S. Government become directly involved on a large scale in agricultural commodity markets.

The story of U.S. Government involvement in the macroeconomy prior to the thirties was similar to that for agriculture. The years after the Civil War saw improvements in banking, promotion of the development of commercial infrastructure, regulation of industry, and enactment of various tariff policies. But, policies designed to stimulate aggregate demand were years away. Even Franklin D. Roosevelt promised to balance the Federal Budget in 1932. The U.S. Government nominally had limited control of monetary policy. However, J.P. Morgan controlled gold reserves rivaling the U.S. Treasury and allegedly averted a monetary collapse in 1907 (*5*). The Federal Reserve System, created in 1913, was inexperienced, as subsequent events during the Depression would show.

The 1930-70 period sharply contrasts with the experience of agriculture throughout most of the rest of U.S. history. The Federal Government's response to the Depression and its aftermath has been well documented—both for agriculture and the general economy (*4, 13, 16*). The Federal Government set price supports for agricultural commodities above market-clearing levels, established marketing orders, took land out of production after World War II, and accumulated stocks throughout the fifties and sixties. Exports were subsidized or sold to needy countries on concessional terms to offset the loss of competitiveness due to the price supports. Fiscal policy evolved in an era of aggregate demand management, while monetary policy targeted interest rates—all under a system of fixed exchange rates.

One of the consequences of this policy environment was that price variability in agriculture in the fifties and sixties was low in relation to previous decades because prices were supported at U.S. Government-determined levels (table 2). A Government market replaced the export market. Support prices above world market levels reduced foreign import demand and encouraged export supply by our major competitors, thereby reducing the role of U.S. exports (table 1). Public stocks and Federal expenditures for agriculture mounted. Export subsidies and credit programs in the fifties and sixties offset the effects of price supports on world markets and reduced Federal expenditures by reducing public stocks (*10*). Interest rate targeting and mildly expansionary fiscal policy created inflationary pressures in the early fifties, late sixties, and early seventies, and produced low and stable interest rates which lessened the debt load of U.S. farmers (table 3). These circumstances worked in conjunction with agricultural policy to stimulate farm output. An increasingly overvalued fixed exchange rate added an implicit tax on exports.

During this period the problems of price variability, a large reliance on trade, and the linkages between U.S. agriculture and the world macroeconomy were masked by a Government-regulated agriculture and by policies designed to manage aggregate demand. As the agricultural imbalances created by this policy mix became apparent, real support prices for wheat, corn, and rice began to drop about 1950 (figs. 2, 3, 4). For cotton, the process of lowering real support prices started later and proceeded more slowly than for grains. U.S. agricultural policy entered a phase of a reduced Government role in supporting commodity prices through the sixties and into the seventies. Target prices and deficiency payments designed to protect farm income without circumventing market price signals became the mainstay of U.S. commodity programs in the seventies. For wheat and feed grains, the process of Government transition from farm price support to income support proceeded quickly, and the relationship of trade to these commodities and the problem of price variability reemerged (tables 1 and 2). For cotton and tobacco, the transitional role of the U.S.

Figure 2

Real Support Prices for Corn and Wheat

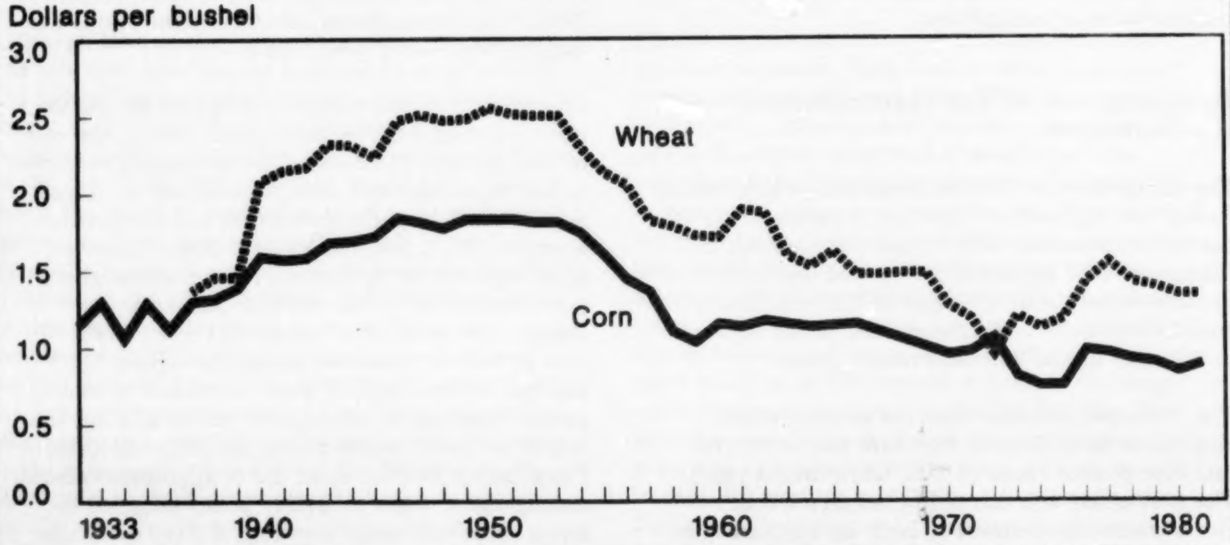


Figure 3

Real Support Prices for Rice

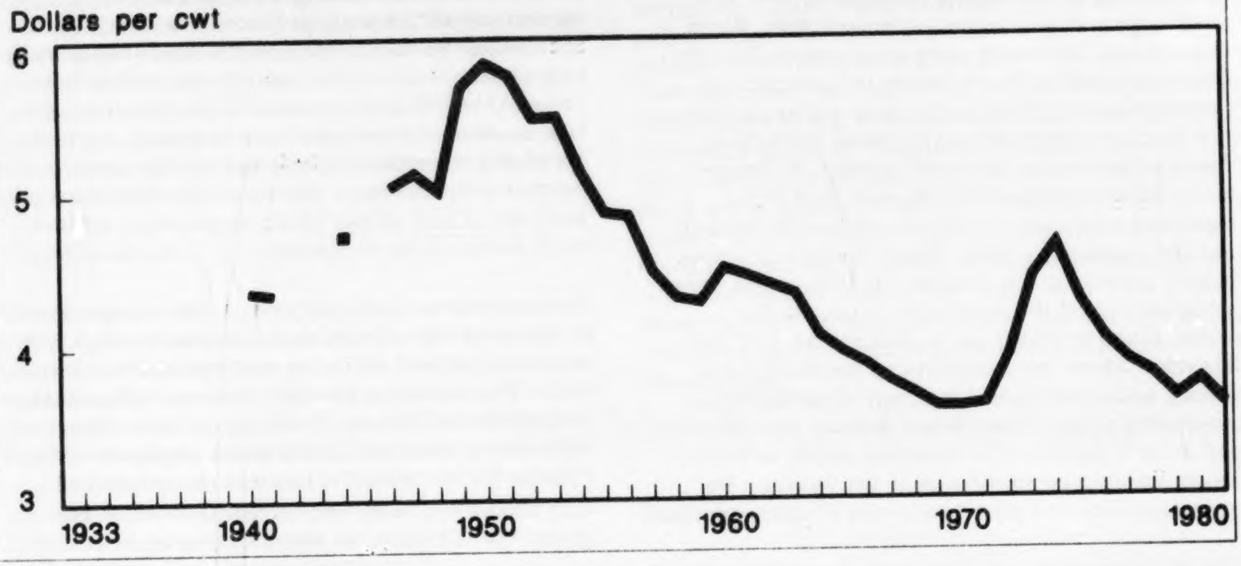
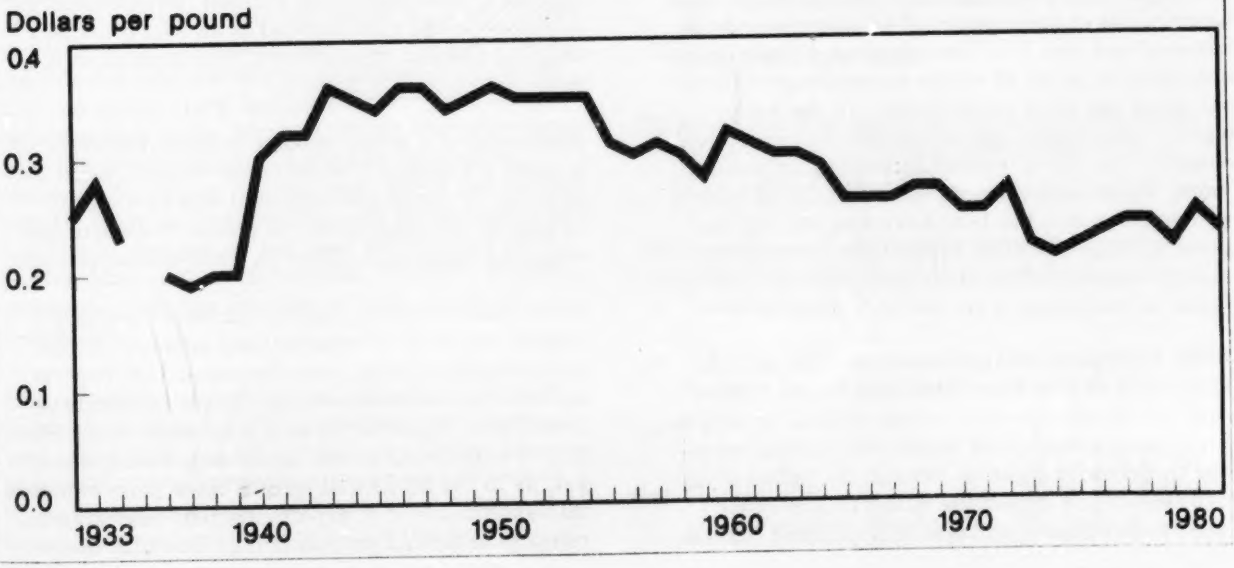


Figure 4

Real Support Prices for Cotton



Government was slower and less complete. Thus, trade has not recovered its traditional importance for these crops, and price variability is less of a problem (tables 1 and 2).

By the early seventies, the imbalances from U.S. macroeconomic policy also became evident. Rapid expansion of the money supply and world liquidity following the oil price increases reduced real interest rates and caused developing nations to borrow funds on international financial markets to finance imports and economic growth. Monetary policy became more erratic as well, first being tightened and then loosened in succession throughout the decade (*6*, p. 291). These changes in money supply growth, in conjunction with the target price policy, increased the variability in commodity prices. Fixed exchange rates were replaced by flexible rates which were sensitive to macroeconomic shocks, adding another dimension of variability to commodity prices. Fiscal policy seemed less effective and more in conflict with monetary policy as Federal expenditures grew in relation to tax receipts. Both unemployment and price levels rose simultaneously.

The policy environment appears to have changed again in the early eighties. In 1979, the Federal Reserve switched from a policy of targeting interest rates to one of targeting the growth of the money supply. The objective of the change was to reduce inflation by maintaining tighter control of the growth in the money supply. Inflation has declined sharply, but at the expense of an increase in both nominal and real U.S. interest rates. Despite a Federal Reserve policy of steady monetary growth, fiscal policy has been expansionary. In the early eighties, the supply-side economists advocated and obtained tax cuts to restore incentives for investment. These achievements have stimulated output and employment, but they have also led to a burgeoning Federal budget deficit. The Federal Government's demand for loanable funds has been a major factor in sustaining high real U.S. interest rates.

These macroeconomic policies have affected U.S. agriculture in two ways. First, the rise in U.S. interest rates has attracted foreign capital, raising interest rates abroad. One result was a global recession in the early eighties. Second, the influx of foreign capital has caused the dollar to appreciate rapidly. Developing and centrally planned nations, who had borrowed heavily at low real rates of interest on short-term credit markets in dollar-denominated accounts, have become vulnerable to both increased interest rates and the stronger dollar. Hence, the major growth markets for U.S. agriculture in the seventies faced severe economic difficulties. In addition to a slowdown in the growth rate of the world market, the stronger dollar has reduced the competitiveness of U.S. exports in relation to those of other exporting countries. Agriculture has been especially affected because price-support programs have prevented the downward adjustment of U.S. prices which would allow agricultural commodities to compete.

On the domestic front, agriculture, as a major user of borrowed capital, has been squeezed by high real interest rates and declining world prices for its products. This situation has led to the worst financial crisis since the thirties. At the same time, deepening public concern about the size and growth of the Federal deficit has led to attempts to reduce Federal budget expenditures, including those on programs like agricultural commodity programs.

The current conflict between U.S. monetary and fiscal policies cannot be sustained in the long run. Growing pressure in Congress to reduce the Federal deficit is a recognition of this fact. Yet, the measures required to bring the budget into balance become increasingly more difficult to implement as increases in the debt load takes an ever-growing share of Federal expenditures. The experience is unprecedented in U.S. history.

Macroeconomic policy appears to be on the verge of a major transition. The character of this transition, however, is uncertain because it will be shaped largely by responses to future events. These changes will have significant effects on trade and agriculture.

These macroeconomic factors, increased world production due to good weather, and adoption of new technologies overseas have decreased U.S. exports and farm prices, deteriorating U.S. net farm income. Loan rates, which in the seventies were rarely effective in supporting prices, again supported the market; as in the fifties and sixties, these price supports implicitly taxed U.S. exports, thereby providing incentives to foreign producers (*15*). The U.S. Government responded by returning to previously used policies, such as the Acreage Reduction Program of 1982 and the Payment-in-Kind program of 1983.

These programs suggest a greater Federal role in U.S. agricultural commodity markets. Such a role is tremendously expensive and is not likely to last without a dramatic change in how these programs are structured, funded, and operated. Thus, U.S. agricultural policy is also in a state of transition as Government officials grope for an effective means to deal with this environment.

Conclusions

The changes in U.S. agricultural and macroeconomic policy in the past two decades have allowed an international environment which the United States once faced to reemerge. Exports are again critical to the health of the agricultural sector. Variability in commodity prices, farm income, and land prices due to uncertain export demand has returned. Fluctuating exchange rates and interest rates add to the volatility of prices and input costs. Income growth both at home and abroad is again critical to U.S. agriculture.

Some aspects of the international environment are different after the passage of the intervening decades. The composition of U.S. agricultural exports has changed in favor of ingredients for livestock feed—namely, corn and soybeans. Some buyers and sellers and the institutions in which they operate are different now. Developing countries and centrally planned nations have replaced Western Europe in importance in trade. Many centrally planned countries are erratic buyers. Imports by developing countries depend on international credit and income growth. Even the institutions used by European nations have changed so that they add to price variability. Most of these differences, however, amplify rather than change the roles of trade and price instability.

The critical question faced by U.S. agricultural officials is how future U.S. agricultural and macroeconomic policy will evolve. Will the United States respond to the reemerged international environment by returning to a policy of intervening directly in commodity markets so as to isolate the agricultural sector from trade and variability and from other sectors? Or, will the United States adopt a policy somewhat like that of the 19th century and the first 30 years of this century, when U.S. policy attempted to provide farm income support without direct intervention in commodity markets? What alternative policies might be adopted to deal with U.S. agriculture in an international context? The answers to these questions will depend largely on changes now taking place in the macroeconomic and trade environment facing U.S. agriculture. When future policy strategies are analyzed, the lessons (both positive and negative) learned by earlier generations of officials and farmers can help us understand in what sense current problems facing agriculture resemble those in the past and in what sense they are unique. This knowledge can provide valuable insights into the formulation of future farm policies.

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Research Review

Sources of International Comparative Advantage: Theory and Evidence

Edward E. Leamer. Cambridge, MA: MIT Press, 1984, 353 pp., $45.00

Reviewed by Stephen W. Hiemstra*

For those willing to accept the challenge, Edward Leamer's *Sources of International Comparative Advantage: Theory and Evidence* is an excellent text. Leamer lays out the theoretical and statistical issues confronted in validating Ricardo's law of comparative advantage[1] and exhaustively reviews resource and trade data. In pursuit of a more perfect understanding of the Heckscher-Olin (H-O) theorem, however, the reader is burdened in the final chapters with weighing the effect of numerous theoretical and statistical assumptions on the author's conclusions. Leamer's contribution accordingly lies with the thorough theoretical and methodological discussions in the earlier chapters.

Leamer begins with the Heckscher-Olin-Vanek (H-O-V) theorem: a country with balanced trade will export services of abundant factors and import services of scarce factors. The H-O-V theorem assumes that factors of production are immobile between countries and hypothesizes that they are used in different combinations to produce a range of goods. Net exports are then defined mathematically as a linear function of an inverse matrix of factor intensities times a vector of excess factor supplies (that is, a relationship among three measurable quantities: trade, factor intensities, and factor abundance). In his statistical model, Leamer postulates a linear relationship between two of these quantities: trade and factor abundance.[2] In estimating this model, he employs quantity, net-export data aggregated at the two-digit level (that is, 10 categories of products) and data on 11 resources for 60 countries.[3]

Most of the book is devoted to Leamer's methods. Chapter 1 reviews the assumptions of the H-O-V theorem:

(1) The number of goods equals the number of resources;
(2) Factors are mobile within countries, but are competitive among countries;
(3) Factor and product markets are competitive;
(4) Perfect knowledge, constant returns to scale, and diminishing marginal productivity exist;
(5) Factor prices are equalized among countries; and
(6) Individuals facing identical product prices consume products in the same proportions.

This inquiry specifies the mathematical model and explores deviations from its assumptions. Leamer's critical deviations include the following:

(1) When the number of resources and products are unequal, the outcome of trade is indeterminant;
(2) When factor prices are unequal among countries, no unique correspondence between resources and products is assured; and
(3) When returns to scale are not constant, trade need not lead to factor price equalization, markets need not be competitive, and the model may violate other assumptions of the H-O-V theorem.

Of these three deviations, Leamer views economies of scale as most likely to affect the pattern of trade significantly.

Leamer discusses several interesting observations in chapter 1. First, at constant output prices, an increase in the supply of a factor will increase the output of the commodity which uses that factor intensively and will reduce the output of the other commodity (the Rybczynski theorem). Second, an increase in the price of the imported good will increase the return to the scarce factor and will reduce the return to the abundant factor (the Stolper-Samuelson theorem). Third, if the number of resources and products are unequal, small transport costs may determine the composition of trade. Fourth, tariffs must be greater than transport costs to affect the pattern of trade. Fifth, nontraded goods do not materially affect the assumptions of the H-O-V theorem.

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[1] David Ricardo, *The Principle of Political Economy and Taxation* (New York: Dutton, Everyman's Library, 1976), pp. 77-93.

[2] In leaving the inverse matrix of factor intensities (that is, shadow prices) out of his empirical model, Leamer tests for absolute rather than comparative advantage.

[3] The products are classified according to the Standard International Trade Classification (SITC) code. The resources include: capital, three classes of labor, four classes of land, coal, minerals, and oil.

Chapter 2 outlines Leamer's methodology. He builds his critique on two points: (1) the law of comparative advantage in the n-good case is imprecisely stated in theory and empirical tests, and (2) alternative trade theories have not yet been effectively articulated. In his first point, Leamer observes that analysis of comparative advantage seldom extends beyond the two-goods case. Furthermore, Leamer explains the Leontief paradox as a misspecified condition for substantiating relative factor abundance.[4]

In his second point, Leamer calls for articulation of alternative trade theories. Rather than evaluate comparative advantage as an abstraction, Leamer, the statistician, prefers to compare it with an alternative hypothesis such as: "The H-O model serves as a more accurate guide for trade policy than the scale economy model" (p. 47). In spite of his concern, Leamer likewise does not test an alternative hypothesis.

Chapters 3 and 4 review the resource and trade data employed in later estimations. Leamer graphs important relationships, tests resource and trade aggregates for statistical properties, and examines export commodity clusters. Export clusters are product groups produced that use similar resources. Export clusters pose a problem because theory suggests that countries will specialize in producing commodities, not clusters of commodities. These clusters may emerge because production externalities exist, diversification reduces market risk, and few countries possess the resources needed to produce the commodities of a given cluster (pp. 78-83). Leamer views the distribution of resources as the most credible and theoretically sound explanation for clustering.

In chapter 5, Leamer states that, for purposes of estimation, the objective "is to 'predict' a randomly selected country's net exports or Gross National Product (GNP) given its endowments" (p. 153). These four assumptions apply:

(1) Errors terms are normal, randomly distributed variables with zero means and constant, unknown variance;
(2) Measurement errors are unimportant;
(3) A linear relationship between resources and products exists; and
(4) The data are adequate for prediction (p. 117).

Based on his review of the data, Leamer hypothesizes that the estimation is complicated by systematic heteroskedasticity, gross measurement errors, and nonlinearities. Furthermore, the estimated relationships are collinear enough so that the structural relationships are also probably collinear. Perhaps for this reason, Leamer uses beta variables in place of t-statistics in selecting variables for his empirical model.

In chapter 6, Leamer summarizes his econometric strategy with these words:

> . . . The approach that will be taken is first to estimate the model using ordinary least-squares methods. Second, these estimates are corrected for systematic heteroskedasticity that is assumed to be a function of GNP. Third, the sensitivity of the heteroskedasticity-adjusted estimates to the deletion of observations is studied to detect gross errors. Fourth, the sensitivity of the ordinary-least-squares regression to chronic measurement errors is explored.[5] Fifth, a Bayesian analysis of the homoskedastic model is performed, including a study of the fragility of the Bayes estimates.[6] Last, nonlinear functional forms are tested.

Leamer answers the following questions with his model:

(1) How well do the 11 measured resources explain trade?

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[4] Leontief compared the capital/labor ratios of imports with exports when he should have compared the U.S. share of world capital and labor supplies in determining relative resource abundance, according to Leamer (pp. 52-53).

[5] In chapter 5, the omission of key observations from the data set significantly affects some variables.

[6] Leamer expends considerable effort in chapter 5 analyzing restrictions on use of prior information and providing examples of their use. These details may interest theoretical econometricians, but they go beyond the scope of this review (pp. 136-54).

(2) Do the coefficients take on surprising values?
(3) Has the structural relation between trade and endowments changed over time?
(4) Which are the most important resources? and
(5) What effect do tariff structures have on the functional distribution of income?

Leamer, unfortunately, does not use these questions to structure the discussion of his results. Instead, he provides running commentary, table by table, of his results. In view of the procedure's complexity, this style of presentation makes evaluating his results difficult. One is left to ponder the relative credibility of the reported observations.[7]

Nevertheless, Leamer answers these questions in chapters 6 and 7. In the context of his work, resources explain trade to the extent that a linear relationship exists between resources and products. Leamer tests for nonlinear relationships and concludes: "this form of nonlinearity does not cause large changes in the interferences, but it does cause substantial changes in labor productivities" (p. 182). This conclusion is supported by cited observations substantiating factor price equalization.[8]

Several coefficients in Leamer's equations do take on surprising values and make surprising shifts. The coefficient for highly skilled labor has the largest beta coefficient, followed by capital, skilled labor, and oil. Highly skilled labor's importance in trade in manufactures declines relative to capital between 1958 and 1975. Another shift for manufactured goods occurred during this period as coal lost significance relative to oil as a source of comparative advantage. Furthermore, capital was a source of comparative advantage and highly skilled labor was a disadvantage[9] in cereal grain exports in 1958; these observations were reversed in 1975.[10] Land resources contributed to comparative advantage in cereal exports in both years, as we might expect.[11]

Leamer reports that skilled labor and capital were the most important resources in 1958 and 1975, respectively, in determining the composition of U.S. exports. He reported that the United States was scarce in capital, skilled and semi-skilled labor, land, minerals, and oil in 1958 and abundant in highly skilled labor and coal. By 1975, capital and the first three classes of land had become abundant.[12]

Leamer assesses the effect of changes in resource endowments and tariffs on trade in chapter 7, but his discussion is hard to follow for lack of clear summary statements.[13] Leamer reminds us that his model is a longrun model of trade; the shortrun motivation of participants and outcomes could be quite different. Beyond this observation, however, the overall implications of Leamer's counterfactual tests are neglected in favor of a continued discussion of model specificiations and mechanics. The concluding pages do not summarize the final chapter, and the few observations cited and discussed provide an almost anecdotal image of his work. Chapter 6 does a better job of summarizing Leamer's results, albeit incompletely.

In spite of a weak ending, Leamer's book adequately covers the theoretical and statistical problems inherent in testing the H-O-V theorem and provides a lengthy bibliography of pertinent literature. Although technically complex, the first five chapters of the book are more readible than most texts of this genre. In view of its complexity and expensive price, however, its appeal is limited to analysts interested in international trade theory and econometrics.

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[7] The author recognizes this problem. In the text he provides disclaimers, such as: "Because of the seriousness of chronic measurement errors, the estimates in this table need not be treated too seriously" (p. 162).

[8] Anne O. Krueger, "Factor Endowments and Per Capita Differences Among Countries," *Economic Journal*, Sept. 1968, pp. 641-59.

[9] Although this result appears credulous at the outset, it is consistent with the Stolper-Samuelson theorem cited earlier.

[10] One has to wonder whether 1975 data might not pose special problems when the H-O-V theorem is tested because of the disequilibrium created in world markets by the oil embargo and world grain shortages of 1973.

[11] In this analysis, the ranking of resources as sources of comparative advantage seems more credible than the magnitude of their contribution in such trade projections (p. 200).

[12] These shifts in resource scarcities add credence to the analysis. In a market economy undergoing technological and institutional change, changes in the relative value of resources are expected—in spite of perfect resource immobility—as an inevitable consequence of economic development. For example, see Albert O. Hirschman's *The Strategy of Economic Development* (New York: W.W. Norton & Company, 1958; The Norton Library, 1978).

[13] This comment applies both to organization and content. At one point in the discussion (p. 191), Leamer presents a table of values for discussion generated from an "optimally selected reallocation of resources." Both the selection process and the precise allocation of resources are unexplained. This lack of explanation seems unusual in a text which earlier provided lengthy discussions of theoretical and statistical techniques.

Made in Washington: Food Policy and the Political Expedient

Clarence D. Palmby. Danville, IL: The Interstate Printers & Publishers, Inc., 1985, 226 pp., $14.95.

Reviewed by Martin E. Abel*

Clarence Palmby observed first hand over nearly 50 years the evolution of U.S. agriculture and agricultural policy in various capacities—as farmer, Government official, market developer, and business executive. Those concerned with U.S. agriculture will benefit from Palmby's insights and experience.

The tone of his book is set in the first sentence: "Prices are made in Washington." Palmby clearly believes that the Government has interfered in U.S. agriculture too much through restricting output and supporting commodity prices. These interventions compounded the surplus problems of the fifties, sixties, and early eighties by encouraging production and discouraging exports and domestic use. They restricted the market place from bringing about necessary adjustments in supply and consumption.

The author, however, is not against any and all interventions in agriculture. He favors:

- Low levels of price supports that do not interfere with the market most of the time but that do provide protection against precipitous price declines,
- International trade liberalization, and
- Market development activities that increase total demand for U.S. agricultural exports longer term.

In short, Palmby is for demand expansion and against controlling supplies.

Some of Palmby's reflections also deal with the political and administrative processes that make U.S. farm policy. He worked in these arenas for several years and thus can speak knowledgeably about what it takes to be effective. He is a realist, recognizing that honest men and women can hold different views and that these differences should be respected. One needs to be patient, yet persistent, in changing policies; sooner or later the power of events will force Government to adjust to reality.

Made in Washington is timely in view of the recent efforts to forge a new farm bill which moves in a direction advocated by Palmby—more reliance on the market and more emphasis on increasing demand. Yet, one senses that policy changes are being driven largely by the current depressed situation in agriculture rather than by long-term considerations. The danger in this situation is that people develop unrealistic short-term expectations and ignore the long-term problem of how once again to achieve demand growth worldwide. Those involved in the policy process could benefit from Palmby's reflections, for they would realize that policy changes do not necessarily yield instant success. It may instead take years before correct policies bear significant fruit.

The book has a number of shortcomings. First, the author assumes the reader knows a lot. Those unfamiliar with the history and technical details of agricultural policies and programs will have a hard time following some sections of the book. Second, Palmby's material is not always well organized, which unnecessarily interrupts the flow of his arguments. Finally, some of the history is incomplete. For example, Palmby extensively discusses the bad features of the 1983 payment-in-kind program which sharply reduced output and raised prices at a time when the United States was losing its competitive position in world markets. He makes no mention, however, of the 1982 farmer-owned reserve program that encouraged farmers to produce and store grain and that artificially supported prices when production should have actually been discouraged and prices been allowed to fall.

Despite these shortcomings, Palmby has written an interesting memoir that is worth reading. One should not ignore hard-earned experience.

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The Handbook of Econometrics

Volume 2. Zvi Griliches and Michael D. Intrilligator (eds.). Amsterdam: Elsevier Science Publishers, 1984, 585 pp., $65.00.

Reviewed by David Freshwater*

Reviewing a book written by a number of authors is an onerous task; reviewing one volume of a series by numerous authors is even more difficult. However, when the series is entitled *The Handbook of Econometrics,* the task is nearly insurmountable. Volume 2 of the handbook contains three parts of unequal length: "Testing," "Time Series Topics," and "Special Topics In Econometrics." The section on "Time Series" comprises the bulk of the volume, having six chapters, while the section on "Testing" has four and the "Topics" section two.

The detailed nature and diversity of the various chapters prohibits comprehensive review of the subject matter in each chapter. Instead, I have decided to evaluate the book from the perspective of what I would call a sophisticated regression runner—that is, an individual with an empirical orientation, but one who has been exposed to a good course in graduate econometrics and has a working knowledge of linear algebra and mathematical statistics. The vast bulk of agricultural economists who might consider consulting a series of volumes with the portentous title, *The Handbook of Econometrics,* would presumably fall into this class.

The editors set themselves the task of creating three volumes which are "...to serve as a source, reference, and teaching supplement for the field of econometrics, the branch of economics concerned with empirical estimation of economic relationships." The focus of the handbook is clearly on the theory of econometrics and not on empirical estimation. This volume presents recent advances in the development of tests of hypotheses, the use of time series models, and the appropriate use of latent and qualitative variables. The material should provide "comprehensive and accessible surveys" to professionals and advanced graduate students. The editors' intent is surely not to create a cookbook of recipes for the neophyte.

Have they met their goal for my sophisticated regression runner? Unfortunately, they have not. Unlike several other handbooks in this series, this volume is not a self-contained book of instructions that would meet the needs of the audience I have defined. The book fails on several grounds. The level of mathematical sophistication generally exceeds that of most applications-oriented agricultural economists. The presentation neither motivates the reader in the sense of setting out critical points nor follows a well-structured path linking individual issues in the various chapters. The three sections could have been improved by a brief introductory comment identifying the objectives and showing how they relate. As currently constituted, the book reads more like a collection of journal articles than a guide or source of information for individuals with limited knowledge of specific topics. Conversely, the advanced econometrician with a strong background and familiarity with econometric and statistics journals is likely to find the handbook a redundant source as it provides little new material.

Of the individual papers, those by Granger and Watson on "Time Series and Spectral Methods in Econometrics," Chamberlain on "Panel Data," Aigner, Hsiao, Kapteyn, and Wansbeck on "Latent Variable Models," and McFadden on "Econometric Analysis of Qualitative Response Models" are the most clearly written, providing the reader with a clear outline of the topic at a level within the grasp of the target audience. These chapters mix verbal and mathematical exposition, enabling the reader to get over the harder spots.

Other chapters emphasize proofs almost to the exclusion of applications, examples, and verbal description. Individuals unfamiliar with the topics would likely need to consult other material prior to reading these chapters. Such problems certainly weaken the value of the volume as a handbook.

Volume 2 of *The Handbook of Econometrics* provides a highly referenced source of frontier topics in econometrics. Each chapter is well referenced for those seeking to explore topics in greater detail. However, all but the most technically sophisticated economists will find the book tough sledding, thereby reducing its value as a handbook. It will rarely be the first source one would consult, but it might prove a most important source if the reader is willing to work slowly through a particular chapter.

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Farm Equipment Innovations in Eastern and Central Southern Africa

Iftikhar Ahmed and Bill H. Kinsey (eds.). Brookfield, VT: Gower Publishing Co., 1984, 333 pp., $31.50.

Reviewed by Richard D. Sigwalt and Darryl S. Wills*

The problems facing agriculture in African nations today are not new. Low productivity, low incomes, and poor weather head the list of familiar problems confronting African farmers, the majority of whom are poor smallholders. One promising avenue for addressing these difficulties lies in the design of improved farm equipment. The editors of this volume set out to discover the current state of farm equipment use in smallholder agriculture and to assess the potential benefits of equipment innovations.

Bill Kinsey is considerably more than the editor of what is, in fact, a loosely structured argument for a systematic, multidisciplinary, and farm-centered approach to transforming peasant agriculture through appropriate technology. He has written four of the six case studies (those on Zambia, Tanzania, Uganda, and Malawi) and has coauthored three introductory and concluding chapters with Iftikhar Ahmed. Case studies on Kenya (by Gichuki Muchiri) and the southern Sudan (by J.D. de Coninck, A. Duncan, and P.E. Winter) and a substantial policy essay by Bruce R. Johnston round out the book.

The case studies are so disparate in theme and quality as to compromise the value of the book as a whole. Certainly the southern Sudan essay, which focuses heavily on how hand tools are supplied and which is based on no actual fieldwork in rural areas, belongs elsewhere. Kinsey's own essays are quite different from one another. The ones on Malawi, where he has worked extensively, and Zambia, where agriculture is already relatively highly mechanized, are particularly good; however, the one on Tanzania is based only on others' work and is far from thorough. Muchiri's piece differs considerably from the area surveys. Rather than surveying Kenya as a whole, Muchiri reports on an experimentation project with available technology with a view to later propagation; however the subject is germane because it exactly reflects the approach Kinsey, Ahmed, and Johnston favor.

From the case studies, the editors conclude that there has been no significant diffusion of new items of equipment for small farmers in East Africa in over two decades. One reason for this situation, they argue, is that past research and development (R&D) activity was both inadequate and inappropriate, operating without regard to what farmers really needed. The editors demonstrate conclusively that gasoline-driven equipment displaces laborers (presumably for urban unemployment), devours scarce capital, and falls into disuse in environments lacking an infrastructure to maintain such equipment. In every respect, they find animal-powered equipment preferable and believe that R&D should aim at inserting such equipment into local economies. An effective R&D program would have researchers study farms as social and economic systems and would identify what parts of those systems suffer constraints, especially seasonal labor constraints, that could be alleviated with improved farm equipment. Existing technology could then be applied to eliminate those particular bottlenecks.

The decision of the editors to include a chapter on policy considerations is wise because government actions not only detemine what types of R&D will be supported (and the extent of that support) but also foster the economic environment in which farmers must choose whether to adopt the results of that research. Even appropriate equipment innovations will not necessarily be adopted by farmers. Widespread acceptance depends on several factors, not the least of which is the price of the equipment relative to expected returns. Other factors include effective demonstration and training and a good transport and storage system to facilitate distribution. Overall government policies directly bear on these factors. Furthermore, Johnston emphasizes the desirability of designing equipment innovations that lend themselves to the creation and expansion of small-scale manufacturing in the countryside. Such a strategy would provide additional sources of employment and income and would expand the productive base of the economy, while conserving essential foreign reserves for other development needs.

One could easily fault the book for not addressing Africa's contemporary food crisis or for not placing it in its overall political and economic context. The case for appropriate technology is ably made (if it still has to be made); programmed innovation works only if it responds to needs and opportunities peasants themselves encounter in their workaday lives. Surely innovation would occur almost spontaneously, as it did in southern Africa a century ago, if peasants were offered attractive markets. If, as is clearly the case, peasants still need to be prodded into adopting improved equipment, why is that so?

---

*Sigwalt is a professor of history at Howard University, and Wills is an economist with the Agriculture and Rural Economics Division, ERS.

Kinsey provides the beginning of an answer in his case study of Malawi. There, a simple winch-type gadget (the "Snail") costing about $700 was found to demand an amount for yearly operation about five times the average peasant's household income.[1] Kinsey finds that the only equipment a peasant has the income to purchase are hand tools such as the traditional hoe and machete. However valuable a farm-systems approach to development is (and it is valuable), it will lead nowhere until exploitation (through artificially low food prices) of the peasant to feed the city ends and until peasants are induced to invest by the simple promise of attractive gain. Until then, the farm-systems approach merely represents an attempt to reconcile technology and poverty.

---

[1] The Snail is a fuel-powered cultivating device designed to permit early planting and increase yields by facilitating the cultivation of dry, hard soils before the seasonal rains.

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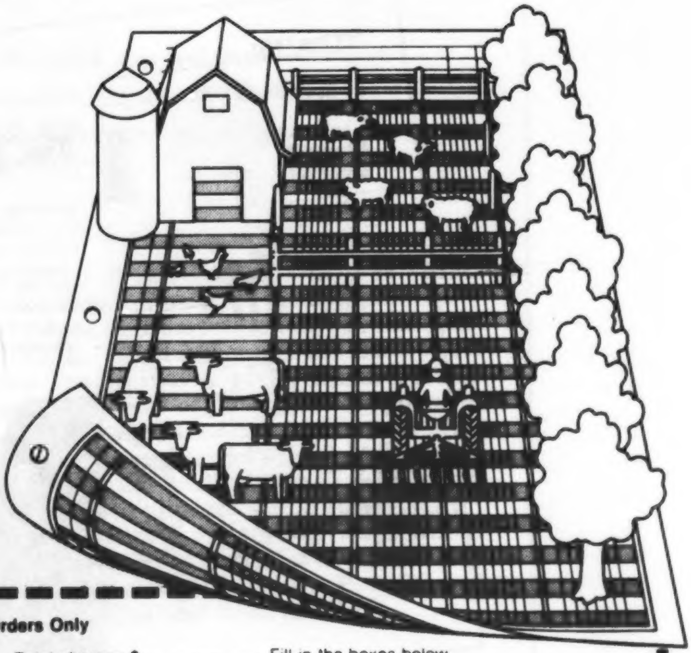

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In This Issue

In the first issue of *Agricultural Economics Research* 38 years ago, O.V. Wells indicated that the new research periodical would publish articles (1) reporting results of economic research supported by the U.S. Department of Agriculture, (2) describing new methods or critically evaluating old methods still in use, and (3) describing new or expanding areas of research or statistics.

Most articles in this journal since then have been in the first category, reporting research results. Yet, the lead article in the new journal was "Designs of Samples For Surveys," by Earl E. Houseman, then a statistical consultant to the Office of the Chief, Bureau of Agricultural Economics (BAE), but later an employee of BAE and the Statistical Reporting Service and a frequent AER contributor. This fact is noteworthy because by leading with this article, the journal emphasized questions about designing samples for social science research. It also represented symbolically the crucial role of the statistician and sample surveys in supporting the quality of data used in economic research. The editor continued this emphasis, carrying eight articles on surveys and sampling questions in Volume 1, compared with seven articles on economic questions. Emphasis over the years shifted more toward economics articles, with the sampling and survey articles appearing in varying frequencies. Articles related to the survey and sampling techniques underlying our data base have been lacking in recent issues.

The recent void disappears with this issue's lead article in which Ford, Nealon, and Tortora compare sampling and nonsampling errors in area frame estimators in agricultural surveys. Reading this article *and* the Houseman article in Volume 1, Number 1, I was struck, not only by how far survey and sampling techniques have advanced in the three decades, but also by the similarity of the problems the two articles address.

The second article by Smale, Saupe, and Salant addresses the research question of using data from sample surveys of farm households in Wisconsin and Mississippi-Tennessee to gain insights into those human resource, farm business, and financial characteristics which contribute to farm household viability.

The final article by Ballenger and Norton departs from survey emphases and presents results of a large-sector model that simulates economic equilibrium. They use a quadratic programming framework for their economic model that analyzes the impacts of Mexican pricing policies on Mexican agriculture and that illustrates the difficulty of designing a support program for a sector when there are multiple policy objectives.

Gerald Schluter

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Area Frame Estimators in Agricultural Surveys: Sampling Versus Nonsampling Errors

Barry L. Ford, Jack Nealon, and Robert D. Tortora*

Abstract

This article describes and compares three area frame estimators used for agricultural surveys and shows the importance of sampling and nonsampling errors to both economists and statisticians. Comparisons among the estimators are based on their applicability, sampling efficiency, and susceptibility to nonsampling errors. The weighted segment estimator has the widest applicability and highest precision, but it also has important nonsampling errors. This article also discusses research conducted to evaluate and reduce the nonsampling errors.

Keywords

Area frame, closed segment estimator, open segment estimator, weighted segment estimator, nonsampling errors

Introduction

Probability surveys that make agricultural estimates often use an area frame. The area frame includes all the land within a specified geographical area, such as the continental United States, and is used to define the sample for a survey. Area frames have been used by the Statistical Reporting Service (SRS) since the early sixties. The June Enumerative Survey (JES), an annual survey which measures planted acreage of crops and numbers of livestock, is an example of a major survey which depends almost entirely on an area frame. Although the use of list frames for probability surveys has increased greatly in recent years, area frames are still needed to measure the incompleteness of the lists.

The Farm Costs and Returns Survey, measuring farm economic values, is an example of a survey that uses an area frame to measure the incompleteness of the list frames. In this case, the lists include only farms with gross sales greater than $100,000; thus, the sample from the area frame to measure the incompleteness of the lists is an essential part of the survey. The sample from the area frame contributes about 50 percent of the agricultural economic estimates. Area frame estimators are a crucial part of almost all probability surveys on which agricultural estimates are based.

SRS area frames are stratified in each State according to several factors, intensity of agriculture on the land being a primary factor. SRS selects a sample from each stratum. Each element of the sample is a continuous parcel of land called a segment. SRS draws the boundaries of each segment on an aerial photograph; enumerators use these photographs when collecting data.

After data collection, SRS uses three estimators: the closed, open, and weighted segment estimators. All three require that the enumerator establish what farms are related to each segment. (For SRS purposes, a farm is defined to be all land under one operating arrangement with gross farm sales of at least $1,000 a year.) The enumerator finds out what portion of the segment is under the operation of each farm. This portion is called a tract, and the enumerator draws the boundaries of each tract on the aerial photograph, accounting for all land in the segment.

---

*The authors are mathematical statisticians with the Statistical Reporting Service, U.S. Department of Agriculture. Ford is the Head of the Crops, Prices, and Labor Surveys Group, Estimates Division; Nealon is the Head of the Sampling Frame Development Section, Statistical Research Division; and Tortora is Director of the Survey Division.

When an enumerator interviews a farmer, the closed segment approach requires that the enumerator obtain data for only that part of the farm within the tract. For example, the enumerator might ask about the total number of hogs on the land in the tract.

The open segment and weighted segment approaches require that the enumerator obtain data on the entire farm. For example, the enumerator would ask about the total number of hogs on all land in the farm. However, the open segment approach uses these data only when the headquarters of the farm is within the segment boundaries. (Thus, the headquarters is used to identify each farm uniquely with one segment.)

Using the weighted segment approach, the enumerator obtains farm data for each tract, but these farm data are weighted; the current weight used by SRS is the ratio of tract acres to farm acres.

The formulas for the three estimators and their standard errors appear in the appendix at the end of this article.

Suppose the following situation occurs for a specific farm: tract acres = 10, farm acres = 100, hogs on the tract = 20, and hogs on the farm = 40. The closed segment value of number of hogs would be 20; the weighted segment value would be 40 × (10/100) = 4; and the open segment value would be 40 (if the headquarters is in the segment) or 0 (if the headquarters is not in the segment).

Comparing the Estimators

Economists and statisticians who wish to obtain data or understand the nature of a particular estimate should be familiar with the distinct advantages and disadvantages of the closed, open, and weighted approaches. This section compares each estimator with respect to its applicability, the size of sampling errors, and its susceptibility to nonsampling errors.

Applicability

One of the most common uses of closed segment estimates is to estimate crop acreages and livestock inventories. An enumerator accounts for all land in each tract by type of crop or use and for all livestock in the tract. The main disadvantage of the closed segment estimator arises when the farmer can report only values for the farm rather than for a tract which is a subset of the farm. For example, "How many tractors do you own?" can only be answered on a farm basis. Thus, the closed segment estimator is not applicable for many agricultural items. Economic items and crop production are two major examples which farmers find difficult or impossible to report on a tract basis.

The open and weighted segment estimators, by contrast, do not have this limitation. They can be used to estimate all agricultural characteristics. This broad applicability is a major advantage for both estimators.

Sampling Efficiency

Sampling efficiency refers to the precision and cost of the estimators. The precision of an estimate can be measured by: (1) the variance of the estimate, (2) the standard error which is the square root of the variance, or (3) the coefficient of variation (CV) which is the standard error divided by the estimate. An estimate becomes less precise as any of these measures increases.

Given the same number of segments to make each estimate, weighted segment estimates are usually more precise than closed segment estimates, and closed segment estimates are usually more precise than open segment estimates (*5, 6, 7*).[1]

Table 1 shows the variances of the three types of estimates from a data set collected in 1982. By comparing the estimated variances, the reader can see that the weighted segment estimates generally have smaller variances than the closed segment estimates, and the closed segment estimates have smaller variances than the open segment estimates. The reduced applicability of the closed segment estimator is clear by the fact that one cannot estimate the number of farms by using only tract information. Thus, there are no closed segment estimates for estimating the number of farms.

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

Table 1—Estimated variances of open, closed, and weighted segment estimates for five farm characteristics, 1982

State	Segments	Estimate	Cattle and calves	Hogs and pigs	Corn acres	Soybean acres	Number of farms
	Number	*Type*			10^{10}		10^{7}
Georgia	436	Open	3.55	1.59	3.66	17.92	1.13
		Closed	2.70	2.88	.49	4.76	NCL
		Weighted	1.22	1.51	.60	3.91	.88
Indiana	324	Open	2.42	18.67	50.12	28.44	1.19
		Closed	2.35	19.74	4.78	4.14	NCL
		Weighted	.89	7.85	2.92	2.15	1.61
Missouri	450	Open	24.11	41.21	10.20	73.36	3.13
		Closed	12.07	29.59	3.75	9.43	NCL
		Weighted	5.20	8.10	2.22	6.88	2.60
North Carolina	391	Open	1.20	1.54	8.09	11.67	2.73
		Closed	.75	6.25	1.82	2.30	NCL
		Weighted	.52	2.35	1.46	1.62	2.12
Ohio	324	Open	6.19	7.81	31.38	20.13	2.16
		Closed	3.02	6.17	3.73	3.36	NCL
		Weighted	1.94	3.68	2.76	1.75	1.37
Total	1,925	Open	37.46	70.81	103.45	151.51	11.14
		Closed	20.89	64.62	14.58	23.98	NCL
		Weighted	9.76	23.48	9.97	16.31	8.58

NCL = Not calculable.

Why would these relationships among the variances occur? Open segment estimates use farm values. Thus, the amount of variability in the value of an agricultural item across the entire set of segments can be great. For example, many segments may have no farm headquarters and get a zero value for a certain agricultural variable; another segment may have one or two headquarters of large farms and get an extremely large value for the agricultural variable. The open segment estimate spreads the agricultural data unevenly throughout the segments.

A closed segment estimate spreads the data more evenly through the segments, and, thus, decreases the variance. For the combined five-State estimates in table 1, this result is especially true for corn and soybean acres, items related directly to land. However, for numbers of livestock, the closed segment estimates are not much better because livestock tend to be in herds or groups that will either be in the tract or not, often forcing the tract value to be either zero or a large value. A weighted segment estimate apportions the farm livestock according to the percentage of the farm acres in the tract. This effect causes the livestock data to be more evenly spread throughout the segments than for either the open or closed segment approaches.

Efficiency also involves the costs of data collection. Because each farmer operating a tract in the segment must be interviewed, the data collection costs for the closed and weighted segment approaches are approximately equal. The cost of collecting only tract data may be slightly less if contacting the farmer is difficult. In this case, the enumerator can usually observe the tract values because the tract boundaries can be established as the enumerator works the rest of the segment. In contrast, the weighted segment estimates require farm values which are much more difficult to observe, and the enumerator would have to put more time into contacting the farmer. However, this cost difference would be slight compared with overall survey costs. Thus, the reader should consider the closed and weighted segment estimates as having the same costs.

An open segment estimate does not require interviewing all farmers with tracts in the segment, but only requires interviewing farmers whose headquarters are located in the segment. Depending on factors such as the dispersion of the sample and the size of farms, the costs of obtaining data for open segment estimates can be 5-20 percent less than for closed or weighted segment estimates. Thus, the open segment approach has a cost advantage, but less precision. To make the open segment estimates as precise as weighted segment estimates would require more segments to be enumerated. Depending on what agricultural item is estimated, the extra cost of these segments may or may not exceed the advantage of a lower cost per segment for the open segment estimates.

Nonsampling Errors

Whereas precision relates to the sample size and the variability of the data, nonsampling errors refer to the effects of biases in the data or estimators. For estimates from large-scale surveys, and agricultural surveys are no exception, nonsampling errors may be of more concern than precision because such errors are harder to control.

Closed Segment Estimates

An accurate measure of the total number of acres within each segment is available prior to interviewing because each segment is delineated on aerial photographs. This measurement provides a control on the total land within the segment accounted for by the enumerator, and it increases the accuracy of the closed segment estimates for crop acreages.

Two types of nonsampling errors occur for closed segment estimates. The first type occurs because there are small areas of waste within the fields. Because of the scale of a photograph, accounting for areas of waste less than 1 acre is particularly difficult. These small waste areas are usually not visible on the photograph and generally cannot be observed from the actual location of the interview. The second type of nonsampling error occurs in some Western States where cattle and sheep roam freely through open gates and cross tract or segment boundaries. In these situations, the operator may not know the exact location of the livestock at the time of the interview and, thus, may not be able to report exactly how many livestock are on the tract at that time. Neither of these types of nonsampling errors is considered serious because research studies have never shown that a consistent positive or negative bias has resulted.

A major advantage of closed segment estimates is their ability to decrease any bias caused by nonresponse. When the farmer refuses to supply information or is inaccessible, the enumerator can usually observe the crops and livestock in the tract. The acreages associated with the crops can be measured from photographs. Often the livestock can be counted; even when they cannot, an indication of their presence allows SRS to do a better job of adjusting for nonresponse (*4*).

Open Segment Estimates

Four important nonsampling errors are associated with open segment estimates. The first is caused by the incorrect application of the "headquarters" rule. Although application of this rule is straightforward for farms run by individuals, the identification of headquarters can become difficult for partnerships, corporations, and managed farms where enumerators need to ask a series of questions to eliminate potential duplicate reporting. SRS has never been able to measure fully the effects of this nonsampling error on the estimates, but it has developed better questionnaires and has stressed the problem during enumerator training to minimize the effects.

The second nonsampling error is the underestimating of the farm population. This error probably arises because the headquarters of farm operators may be inadvertently missed in more densely populated areas. For most farmers, the headquarters is the home, and if the home is in town or in a subdivision, an enumerator may have difficulty identifying that home as the residence of a farmer, especially if the farmer does not consider farming as the primary occupation. Other factors may contribute to this underestimation.

The third nonsampling error is the underreporting of farm values. The reader should consider the effect on a farmer when interviewed by an enumerator. To obtain tract values, the enumerator shows the farmer an aerial photograph on which the precise boundaries of the farmer's tract are drawn. Then the farmer is asked to report values associated with that specific piece of land. When farm values are obtained, there is no map. Both enumerator and farmer must switch into the more nebulous concept of "the farm," that is, the land operated by this farmer. Farmers tend to forget about parcels of rented land not contiguous with the main part of their farm and about parcels of woodland or wasteland under their control, but considered "nonagricultural."

A fourth nonsampling error can occur when the farmer reports livestock data. The enumerator asks the farmer about livestock on the land operated *regardless* of the ownership of the livestock. However, a farmer tends not to report livestock on the farm that are owned by someone else. This typically happens when the farmer is feeding livestock (under contract) owned by someone else. A farmer also tends to report livestock owned by the farmer, but located on someone else's land.

Weighted Segment Estimates

This section is more detailed and quantified than the previous two sections because of the large amount of SRS research to evaluate the nonsampling errors of the weighted segment estimates. SRS believed that the research was warranted because of the advantages in applicability and precision of weighted segment estimates over closed and open segment estimates. This research began when SRS reinterviewed a subset of respondents after the 1974 JES (*3*). Respondents were again asked many of the JES questions about their farms and were then asked to reconcile any differences between the original JES responses and their responses during the reinterview. The evaluation, which was small in scope, involved reinterviews with only 163 JES respondents in Nebraska.

Comparing the original weight with the reconciled weight, SRS found 44 differences out of the 163 reinterviews (27 percent) caused by incorrect responses. Exactly half the differences were positive and half were negative. The effect of the reconciled weights on the weighted segment estimates of hogs and cattle caused biases of -9.6 percent and -0.2 percent, respectively.

SRS also estimated the biases associated with the components of the weighted segment estimates. The estimated biases were as follows: acres in the tract, 0.3 percent; acres in the farm, -5.6 percent; hogs on the farm, -2.5 percent; and cattle on the farm, -2.4 percent. Thus, the concept of farm acres caused the largest bias.

The results of the 1974 JES reinterview were sufficiently troubling that SRS planned a detailed reinterview with a large sample size after the 1976 December Enumerative Survey (DES). The DES reinterview involved 528 respondents in three States: Indiana, North Carolina, and Oklahoma. Table 2 shows the biases in weighted segment estimates for hogs and cattle in the three States and the significance levels from statistical tests of whether the biases were significantly different from zero.

Table 2—Estimated bias in the weighted segment estimates for hogs and cattle and the alpha level from each statistical test, 1976

State	Interviews	Hogs and pigs		Cattle and calves	
		Bias	Alpha level	Bias	Alpha level
	Number	*Percent*		*Percent*	
Indiana	149	-11.7	0.15	-4.5	0.02
North Carolina	172	-16.9	.01	-.3	.96
Oklahoma	207	2.2	.42	-3.4	.36
Total	528	-10.9	NA	-3.0	NA

NA = Not available.

When investigating biases in the components of the weighted segment estimates, SRS found that problems in the denominator of the weight—farm acres—were the most serious. For the three States, 44 percent of the farmers who were reinterviewed reported a different number of farm acres. These differences were not offsetting and resulted in the following estimated biases for the farm acres that had been collected on the DES: Indiana, -2.9 percent; North Carolina, -9.9 percent; and Oklahoma,

–4.8 percent. Thus, a farmer tended to underreport the acres in the farm, a result which was consistent with the 1974 reinterview study in Nebraska.

This DES study also obtained the reasons for differences between the original responses and the reinterview responses. Of the differences, 19 percent occurred because the farmer estimated the acreage rather than taking the time to account for the exact acres in the farm. Fifteen percent of the differences were caused by problems in reporting parcels of woodland or idleland which had no crops or livestock. Thirteen percent of the differences involved land rented by or rented out by the farmer. Thirteen percent involved farmers who simply miscounted their acreage. Eight percent could only be attributed to the fact that a different respondent participated in the reinterview than in the DES. The remaining 32 percent reflected miscellaneous reasons such as inclusion of land that was to be sold in the near future, incorrect readings of JES photographs, and farmers who did not remember the initial JES interview.

The authors of the study decided that the underreporting of parcels of woodland or idleland was the main reason for the negative biases in reporting farm acres (*8*). Parcels of woodland and idleland mixed into the agricultural land were more typical of farming conditions in North Carolina (a bias of –9.9 percent in farm acres) than in Indiana (a bias of –2.9 percent in farm acres). The other major reasons for differences caused both negative and positive differences in the farmers' responses, while omission of parcels of woodland and idleland always caused a negative difference.

Panel discussions with enumerators in seven States before the 1982 JES confirmed the problem of obtaining accurate farm acres on the JES:

> Interviewers consider this section to be one of the hardest to get correct answers on; intensive probing is often required. Respondents often do not know the exact acreages offhand. Many operators report only cropland, omitting other types of land such as woodland and wasteland. (*12*)

In summary, closed segment estimates would be the best to use except that their restricted applicability can be an insurmountable problem for survey designers. Thus, weighted segment estimates appear to be the best alternative if the costs are not prohibitively high when compared with the costs of the open segment estimates. SRS now uses all three estimates for its JES because no one type of estimate is clearly the best for every agricultural item estimated by the survey. However, this situation adds more burden on the respondent and greater complexity to the questionnaire.

Research on Alternative Weighted Estimators

How can weighted segment estimates be improved? SRS has recognized that the prevention of nonsampling errors, especially trying to get farmers to give exact acreages rather than best guesses, is extremely difficult. Thus, SRS has decided to concentrate its research on the investigation of alternative weighting schemes for the weighted segment estimator.

Weights Defined by Agricultural Land

SRS evaluated an alternative weighting scheme in 1980 based on total land minus woodland, wasteland, and other nonagricultural land. This weight should have been less susceptible to bias than the operational weight because it subtracted from the numerator and denominator the type of land that was the major source of bias with the operational weight.

The operational and alternative versions of the weighted segment estimator were compared in three States during the 1980 JES for three important farm characteristics: number of farms, total cattle, and total hogs. Table 3 shows the relative difference between the two types of weighted segment estimates for each of the three farm characteristics. The differences between the two estimates were quite small in most instances. Thus, the study did not show that the alternative weight was less biased than the operational weight.

Some nonsampling errors associated with the alternative weight surfaced during the study. The most serious error centered on a discrepancy when farmers reported nonagricultural land at the tract level and the farm level. At the tract level, farmers were instructed to exclude not only woods and other blocks of nonagricultural land but also waste within

Table 3—Relative difference between operational and alternative weighted segment estimates, 1980

State	Segments	Relative difference[1] Number of farms	Relative difference[1] Cattle and calves	Relative difference[1] Hogs and pigs
	Number	*Percent*		
Minnesota	343	3.5	0	–0.5
Ohio	324	3.3	4.7	–2.5
Wisconsin	310	1.0	–1.2	–.1
Total	977	2.6	.3	–.8

[1] Relative difference = 100 (alternative-operational)/operational.

an agricultural field. The author of that study concluded that when reporting for the farm, farmers did not exclude small parcels of waste within agricultural fields (*2*). Therefore, some nonagricultural land was included in the denominator of the weight, producing an downward bias in the alternative weight.

SRS tested a modified alternative weight in five States during the 1981 JES. This modified weight did not include within-field waste. The estimates were compared between the operational and alternative weighted segment estimates for the same three farm characteristics evaluated in 1980. The estimates were remarkably similar again. The alternative weighting scheme was not less susceptible to an upward bias than the operational scheme. Numerous nonsampling errors associated with the alternative weight were identified during the studies (*9, 10*). Thus, SRS decided to investigate a less complex alternative weight.

Weights Defined by Cropland

SRS collected data on cropland weights during the 1982 JES in five States. Cropland was defined as land planted or to be planted to crops during 1982, idle cropland, summer fallow, and cropland used only for grazing or pasture. Field waste was excluded from the cropland acreage for both the tract and farm to avoid the problems encountered during the 1981 study.

Eleven percent of the farms in the five States had no cropland. Cropland acreage for the farm was missing for another 12 percent of the operations. SRS adjusted the estimation procedures to account for the data on these operations. Thus, the cropland weight quickly ran into problems that annoyingly complicated the estimation.

The relative differences between the two types of weighted segment estimates are shown in table 4. The significance level from the paired t-tests comparing the estimates are also shown because there were many significant differences. The estimates for the number of farms and cattle inventories were significantly higher for the operational estimates in Georgia, Missouri, and North Carolina and for the total combined. These results indicate that the cropland weight is less susceptible to an upward bias than the operational weight. The three States with considerably more noncropland—Georgia, North Carolina, and Missouri—were the States where the two types of weighted segment estimates were significantly different.

In reporting on their 1982 research, Dillard and Nealon concluded that the cropland weight did not appear to be as biased as the operational weight (*5*). Two disadvantages of the cropland weights were that: (1) 23 percent of the operations had cropland that was either zero or missing, and (2) the CV's were slightly higher for the estimates using the cropland weight.

Further Research

SRS will continue attempting to reduce the nonsampling errors of the weighted segment estimator that is used operationally. The applicability of this estimator plus its high precision call for this continued research. The agency will also test new weighting schemes. The most recent research proposal is to weight by the size of the major agricultural item of each farm (*1*). If a farm has cropland, the major item will be the crop with the most acreage. If a farm has no cropland, the major item will be the type of livestock that are most numerous. Preliminary research has indicated an optimistic outlook for this estimator.

Statisticians still tend to compute sampling errors and make their decisions based only on them. In the case of SRS, the weighted segment estimator was implemented operationally almost as soon as

Table 4—Relative difference between the operational and alternative weighted segment estimates and the alpha level from each statistical test, 1982

State	Segments	Number of farms		Cattle and calves		Hogs and pigs	
	Number	*Relative difference*	*Alpha level*	*Relative difference*	*Alpha level*	*Relative difference*	*Alpha level*
Georgia	436	–7.4	0.01*	–19.4	0.01*	2.2	0.83
Indiana	324	.3	.81	–2.0	.38	.6	.76
Missouri	450	–5.3	.01*	–10.8	.01*	2.2	.67
North Carolina	391	–13.0	.01*	–29.6	.01*	1.9	.80
Ohio	324	–2.4	.07	–5.3	.09	.8	.79
Total	1,925	–5.5	.01*	–11.3	.01*	1.1	.63

*Denotes a significant difference at the 0.05 alpha level. Relative difference = 100 (cropland-operational)/operational.

SRS observed the decreased variance. However, 10 years after research began, SRS is still trying to identify and eliminate the nonsampling errors involved (*11*). The overall effect of SRS's research is to illustrate the importance and difficulty of assessing nonsampling errors when one searches for the "best" estimator. First, identifying all the nonsampling errors that come, often subtly, into play is difficult. Second, once identified, nonsampling errors are extremely difficult to measure. The very studies designed to assess the effects of the nonsampling errors will have their own nonsampling errors. Third, once measured, nonsampling errors may be difficult (or impossible) to prevent or correct. For survey designers, working with nonsampling errors can be a tortuous obstacle course.

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Appendix: Formulas for the Area Frame Estimators

Each area frame estimator can be described by the following notation. For some characteristic, Y, of the farm population, the sample estimate of the total for the closed segment estimator is:

$$Y_c^* = \sum_{i=1}^{s} \sum_{j=1}^{p_i} e_{ij} \sum_{k=1}^{n_{ij}} y_{ijk} \tag{1}$$

where:

s = the number of land-use strata;

p_i = the number of substrata in the i^{th} stratum;

n_{ij} = the number of segments sampled in the j^{th} substratum in the i^{th} stratum;

e_{ij} = the expansion factor or inverse of the probability of selection for each segment in the j^{th} substratum in the i^{th} stratum;

$$y_{ijk} = \begin{cases} \sum_{m=1}^{f_{ijk}} t_{ijkm} & \text{if } f_{ijk} > 0 \\ 0 & \text{if } f_{ijk} = 0 \end{cases} \tag{2}$$

f_{ijk} = the number of tracts in the k^{th} segment, j^{th} substratum, and i^{th} stratum, and

t_{ijkm} = the tract value of the characteristic, Y, for the m^{th} tract in the k^{th} segment, j^{th} substratum, and i^{th} stratum.

For the open segment estimator, the sample estimate would be the same form as Y_c^*:

$$Y_o^* = \sum_{i=1}^{s} \sum_{j=1}^{p_i} e_{ij} \sum_{k=1}^{n_{ij}} y_{ijk} \tag{3}$$

except here:

$$y_{ijk} = \begin{cases} \sum_{m=1}^{f_{ijk}} b_{ijkm}\, y_{ijkm} & \text{if } f_{ijk} > 0 \\ 0 & \text{if } f_{ijk} = 0 \end{cases} \tag{4}$$

b_{ijkm} = 1 if the farm headquarters is within the segment
0 if the farm headquarters is not within the segment

y_{ijkm} = the value of the entire farm for the m^{th} tract in the k^{th} segment, j^{th} substratum, and i^{th} stratum

The weighted segment estimator would also be of the same form:

$$Y_w^* = \sum_{i=1}^{s} \sum_{j=1}^{p_i} e_{ij} \sum_{k=1}^{n_{ij}} y_{ijk} \tag{5}$$

but with the distinction that:

$$y_{ijk} = \begin{cases} \sum_{m=1}^{f_{ijk}} a_{ijkm}\, y_{ijkm} & \text{if } f_{ijk} > 0 \\ 0 & \text{if } f_{ijk} = 0 \end{cases} \tag{6}$$

a_{ijkm} = the weight for the m^{th} tract in the k^{th} segment, j^{th} substratum, and i^{th} stratum.

Operationally, SRS has used the weight:

$$a_{ijkm} = \frac{\text{tract acres for the } m^{th} \text{ tract}}{\text{entire farm acres for the } m^{th} \text{ tract}} \tag{7}$$

since the early seventies.

For all three estimators, the formula for the estimated variance can be written as:

$$\mathrm{Var}\,(Y^*) = \sum_{i=1}^{s} \sum_{j=1}^{p_i} \frac{(1-\frac{1}{e_{ij}})}{(1-\frac{1}{n_{ij}})} \sum_{k=1}^{n_{ij}} \left(y'_{ijk} - y'_{ij\cdot} \right)^2 \quad (8)$$

where:

$$y'_{ijk} = e_{ij} y_{ijk} \quad (9)$$

$$y'_{ij\cdot} = \frac{1}{n_{ij}} \sum_{k=1}^{n_{ij}} y'_{ijk} \quad (10)$$

The standard error is then:

$$\mathrm{SE}(Y^*) = \{\mathrm{Var}\,(Y^*)\}^{1/2} \quad (11)$$

In Earlier Issues

This fact that a sample can be more accurate than a census, under certain conditions, is becoming widely accepted. The explanation is simple. With the exception of rather unusual cases, surveys and censuses are subject to many errors which have little, if anything, to do with the way a sample is selected. The challenging problem is often how to get accurate and useful information from respondents, or how to keep errors due to causes other than sampling at a minimum—not how to design an efficient and adequate sample.

Earl E. Houseman
Vol. 2, No. 3, July 1950

Farm Family Characteristics and the Viability of Farm Households in Wisconsin, Mississippi, and Tennessee

By Melinda Smale, William E. Saupe, and Priscilla Salant*

Abstract

The authors used data from sample surveys of farm households in Wisconsin, Mississippi, and Tennessee to examine the relationship of farm household viability to human resource, farm business, and financial characteristics. Viability is measured as the ratio of farm and nonfarm income to consumption expenses, capital replacement costs, and principal payments. Households are grouped by region, gross sales, farm type, operator off-farm employment, and farm business plans. Regression results indicate that factors associated with viability differ by household group. Farm size is associated positively with viability only for larger full-time farmers in Mississippi and Tennessee and for households planning to leave farming.

Keywords

Farm viability, family farms, farm households, Wisconsin, Mississippi, Tennessee

Introduction

The incidence of financial stress among farm families differs by farm type, maturity of operation, and organizational factors; in fact, the overall failure rate of farm businesses is severe and threatens the continued existence of many family farms. In October 1984, one-fourth of the farm loan portfolio of the Farmers Home Administration was delinquent (*1*).[1] In 1984, about one-fifth of all farmers had debt-asset ratios above 40 percent, a level indicating severe debt-repayment difficulties. One-third of farmers with annual sales over $40,000 had debt-asset ratios higher than this critical level. These operations were large- and medium-size farms, and most were full-time family farms (*2*).

In this study, we used cross-sectional data from farm household surveys in Wisconsin, Mississippi, and Tennessee to examine the viability of individual farm households. Farm business and household characteristics are reported for selected groups of farm households, by survey region. We tested characteristics hypothesized to be associated with farm viability and compared groups using regression analysis.

This study provides new information on the characteristics of farm families and factors affecting their financial condition. The analysis uses farm family data from selected areas in Wisconsin, Mississippi, and Tennessee to measure the viability of individual farm households. We grouped farm households by major organizational attributes and tested the effects of differences in human resource, farm business, and financial characteristics on a farm's potential for success. For the Wisconsin area, selected groups include households that operate dairy farms. For both the Wisconsin and Mississippi-Tennessee survey areas, selected groups include households in which the operator farms part-time, households with smaller farms (annual sales under $20,000), households with larger farms (annual sales $20,000 or above) on which the operator farms full-time, and households in which the operator is planning to leave farming.

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

USDA's 1981 and 1983 Family Farm Surveys were designed to link farm business data with characteristics of the family on the farm. The surveys studied and gathered new information about the characteristics of farm families, family labor use, farm business organization, farm financial characteristics, sources of household income, and perceived problems and goals of farm families. Data revealing characteristics of both the farm family and the farm as a producing unit are not generally available through other USDA series or the *Census of Agriculture* or *Census of Population.*[2]

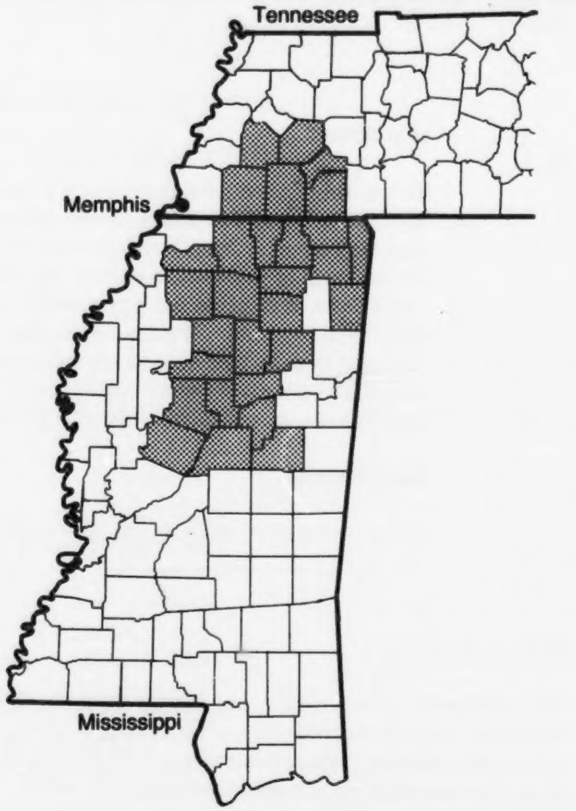
The Mississippi-Tennessee Family Farm Survey (1981) covered 1,087 households in a contiguous 29-county area in northern Mississippi and southwestern Tennessee (*3*). The Wisconsin Family Farm Survey (1983) covered 529 farm households in an eight-county area in southwestern Wisconsin (*4*).

Although survey results can be generalized only to the counties included in the samples, the survey sites were selected because they share common features with larger segments of U.S. agriculture. The southern site typifies parts of the Southeast and Piedmont, where farming is an important economic activity, but farms are relatively small. The Wisconsin site is typical of other North Central and New England areas where dairying is the most common farm type and most farms are family enterprises.

The Mississippi-Tennessee site lies in the Sand-Clay Hills region, a low-income agricultural area dominated by small farms (fig. 1). Most of these small farms are beef cattle operations (excluding feedlots), with some soybean, cash grain, and cotton enterprises. The metropolitan area of Jackson, TN (population of 50,000), and a number of smaller towns (populations under 12,000) provide some off-farm employment.

Figure 1

Mississippi-Tennessee Family Farm Survey Site



The Wisconsin site is in the unglaciated hills of the southwestern portion of the State (fig. 2). A low-income area in relation to the State, the site is not depressed according to national criteria and has a higher average income than the Mississippi-Tennessee survey area. About two-thirds of the Wisconsin farms are dairy operations, and the remainder are cash grain, beef cattle, and other livestock operations. LaCrosse (population of 51,000) and four smaller towns (populations between 5,000 and 6,200) provide some off-farm employment opportunities.

Roughly 12,000 farm households were represented in each site. The sample was drawn with a stratified two-stage cluster design in the Mississippi-Tennessee

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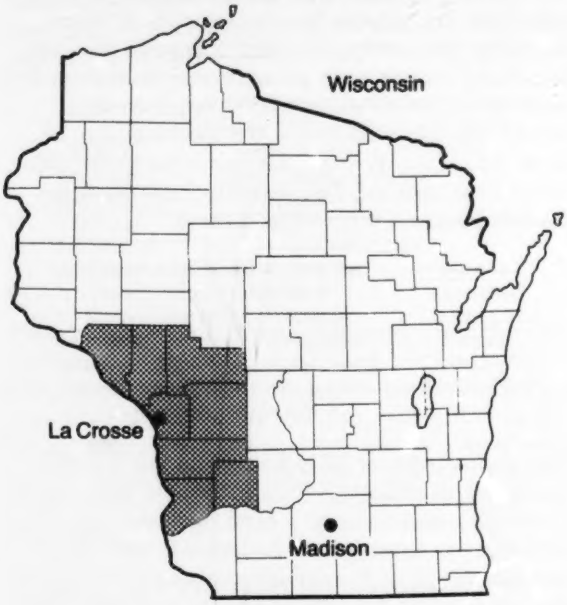
[2] An exception is the "1979 Farm Finance Survey," a followup to the *1978 Census of Agriculture.*

Figure 2

Wisconsin Family Farm Survey Site



site and was selected at random from a list of operators in Wisconsin. In both areas, households were contacted to determine whether they qualified as "family" farms, and only eligible households were included in the survey. A farm was defined as a business producing at least $1,000 of agricultural sales in a normal year. The farm was considered a "family" farm if it was not operated by a hired manager, a nonfamily corporation, or an institution.

Trained enumerators conducted personal, onfarm interviews with the farm operator, identified by the household members as the person responsible for major administrative, managerial, and daily operating decisions.

Method

To survive each year, a farm household must generate annual cash income sufficient to provide for the livelihood of its members. To continue operating the farm business, as currently organized, the farm household must cover cash expenses associated with farm production and regularly replace capital stock to sustain the stock's serviceability. To maintain its line of agricultural credit, the farm household must also meet scheduled payments toward loan retirement. Meeting consumption expenses, production expenses, capital replacement costs, and interest and principal payments is a minimum financial obligation for the year-to-year survival of the farm household.

This study's unit of observation is the household of a farm operator, and the accounting period corresponds to 1 year. Because the household's minimum financial obligations toward consumption, production, replacement of capital stock, and loan retirement must be met with cash expenditures, the authors used a cash concept of household income. The cash income concept excludes farm inventory changes and the imputed rental value of the farm residence. The income and expenditure concepts and terminology of this study are consistent with those used in the U.S. Department of Agriculture's (USDA) income accounts series (*5*, pp. 1-5).

The economic activity common to the survey households is the operation of a farm business. The earnings of the farm business are measured as net cash income from farming. Net cash income from farming is calculated as the sum of cash marketings of crops, livestock, and products, plus Government payments and other farm income from machine hire and recreation, minus intermediate product expenses of farm origin (such as feed) and nonfarm origin (such as fertilizer), business taxes, business interest, cash wages, and rent paid. In addition to net cash income from farming, survey households receive (1) off-farm employment income from wages and salaries and (2) unearned income (such as nonfarm asset income and transfers). These latter sources of income are important for many of the farm households surveyed; on small, part-time operations, off-farm employment may constitute the primary source of income.

From these combined sources of net cash income, each household must meet annual consumption, capital replacement, and loan retirement obligations. Annual consumption expenditures include the costs of basic needs such as food, clothing, and health care, the timely replacement of consumer durables, and payment of income and Social Security taxes. In this study, we used Federal poverty-level income criteria as a measure of minimum consumption needs.[3] Annual cash expenditures to maintain capital stock represent the replacement of obsolete or damaged capital. These annual replacement costs are distinct from investment to expand the productive capacity of the farm business. In this study, estimated capital replacement costs were calculated at 10 percent of the value of all farm machinery, trucks, and cars. We calculated loan retirement payments, or estimated principal payments, on the basis of the type of collateral under which individual loans were secured (see the glossary at the end of this article).

If the farm household's combined sources of income, as previously defined, are adequate to meet these minimum financial obligations, both the farm business unit and the farm household as a consuming unit are viable. The authors define "viability" as a level of annual cash income sufficient to cover farm operating costs, meet the household's minimum consumption needs, replace capital items at a rate that ensures constant serviceability of the capital stock, and finance loan retirement as scheduled. Under this definition, a viable farm household will both survive and enhance its equity position through retiring loans. If total cash income from combined farm and nonfarm sources exceeds minimum financial obligations, the balance can be used to increase consumption, invest in human capital, expand the farm business, or accumulate nonfarm savings or investments.

To measure f[illegible]sehold viability, we developed a "viability r[illegible]which expresses the capacity of the farm house[illegible]d to meet minimum financial obligations, under the survey-year business and labor organization of the household.[4]

The ratio is generally constructed as follows:

$$\text{viability ratio} = \frac{\text{annual household net cash income}}{\text{annual household financial obligations}}$$

The composition of terms in the viability ratio is determined by the household's farm business plans, as stated by the family in the survey. For families intending to continue farming over the 5 years following the survey, the ratio compares observed household income with an estimated minimum level required to satisfy consumption requirements, replace capital to maintain the serviceability of farm capital stock, and meet loan retirement payments as scheduled. The viability ratio for these households is constructed as follows:[5]

$$\frac{\begin{array}{c}\text{annual}\\ \text{household}\\ \text{cash income}\end{array}}{\begin{array}{c}\text{annual}\\ \text{financial}\\ \text{obligations}\end{array}} = \frac{\begin{array}{c}\text{net cash income from farming}\\ +\text{ off-farm employment}\\ \text{income} + \text{unearned income}\end{array}}{\begin{array}{c}\text{estimated minimum consump-}\\ \text{tion} + \text{estimated capital replace-}\\ \text{ment costs} + \text{estimated loan}\\ \text{principal payments}\end{array}}$$

This ratio compares total household income with the financial obligations the household must meet to continue operating as a farm business and as a farm family. Among farm households planning to continue farming, households with a ratio greater than or equal to 1.0 will be able to maintain their current (survey-year) operation. Those with a ratio less than 1.0 will be unable to meet all their obligations without making adjustments.[6]

For farm families intending to leave farming during the 5 years following the survey year ("farm exit households"), the viability ratio compares estimated total household income with the household's minimum consumption requirements. These households are assumed to retire all outstanding debt by liquidating assets. Thus, they are no longer obligated to make principal payments. Because they are no longer farming, they also have no obligation to replace capital. The viability ratio for farm exit households relates the sum of estimated annual income from the value of net worth, estimated wage income, estimated Social Security benefits, and observed transfer payments to estimated minimum consumption, as follows:

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[3] The poverty-level income criteria are based on the cost of a nutritionally adequate diet plus a proportional allowance for other consumption items, adjusted by family size. Poverty-level income represents a minimal level of consumption. In 1983, for example, poverty-level income was about $10,000 for a family of four. At that level, the household could probably neither save nor invest in self-improvement.

[4] This condition is imposed because the net effect of a change in labor allocation or business organization is difficult to predict. Households under financial stress will probably adjust the size or organization of the farm business. These adjustments may also be accompanied by changes in the allocation of household labor, both among members and between farm and off-farm work. Although these changes will probably alter net income, the magnitude of the changes cannot be estimated without additional information.

[5] Components of the ratio are defined in the glossary.

[6] Although these households may continue to operate in the short run by foregoing capital replacement, for example, they will not be able to survive in the long run under the year-of-survey business and labor organization of the household.

$$\frac{\text{annual household cash income}}{\text{annual household obligations}} = \frac{\text{estimated annual income from value of net worth + estimated wage income + estimated Social Security payments + transfer payments}}{\text{estimated minimum consumption}}$$

Farm exit households with a ratio greater than or equal to 1.0 will be able to satisfy minimum consumption requirements if they cease farming. Those with a viability ratio of less than 1.0 will have difficulty meeting minimum consumption requirements if they cease farming under the current (survey year) business and labor organization of the household.

Identifying Household Groups

Farm households differ in terms of the characteristics that determine their viability. For the household surveyed, these characteristics include primary commodity produced, size of the farm operation, importance of farm and off-farm sources of income, and farm business objectives.

To control for the effects of these attributes on variability in the viability ratio, we grouped sample households into mutually exclusive categories consisting of: (a) farm households in which the operator is planning to leave farming (each survey area), (b) dairy farm households (Wisconsin area only), (c) households in which the operator farms part-time (each survey area), (d) households with a full-time operator and gross sales under $20,000 (each survey area), and (e) households with a full-time operator and gross sales of at least $20,000 (each survey area).[7] The logic of household selection is illustrated in figure 3. Criteria for sorting sample households were developed so that within-group differences in human resource and farm business characteristics were minimized and between-group differences were maximized. In the case of part-time farmers, for example, we tested several alternative definitions to create groups homogenous in terms of operator age and education as well as farm type. We made similar tests in defining "smaller" and "larger" farms with full-time operators.

Because agricultural production processes, human resource characteristics, and nonfarm labor markets differ between the two areas, we disaggregated data by survey region within each farm household group. Differences in farm household characteristics between the survey regions also suggest that data from the two sites are better analyzed separately.[8]

Profiles of Farm Household Groups

Table 1 shows selected human resource, farm business, and financial characteristics of the sample households by region and household group. The data demonstrate observable differences among groups in the level and composition of these resources.[9]

Dairy Farm Households

The average Wisconsin-area dairy farmer was 44 years old. Dairy farms produced average gross sales of $84,916 in 1982, with 191 crop acres and 45 cows. Farm families controlled an average of $368,991 in total assets and $273,061 in net worth. Dairy farm households had an average debt-asset ratio of 0.26. They received 75 percent of their total income from the farm business and approximately 15 percent from off-farm employment. Although these households reported an average total net income of $28,176, 47 percent had viability ratios under 1.0.

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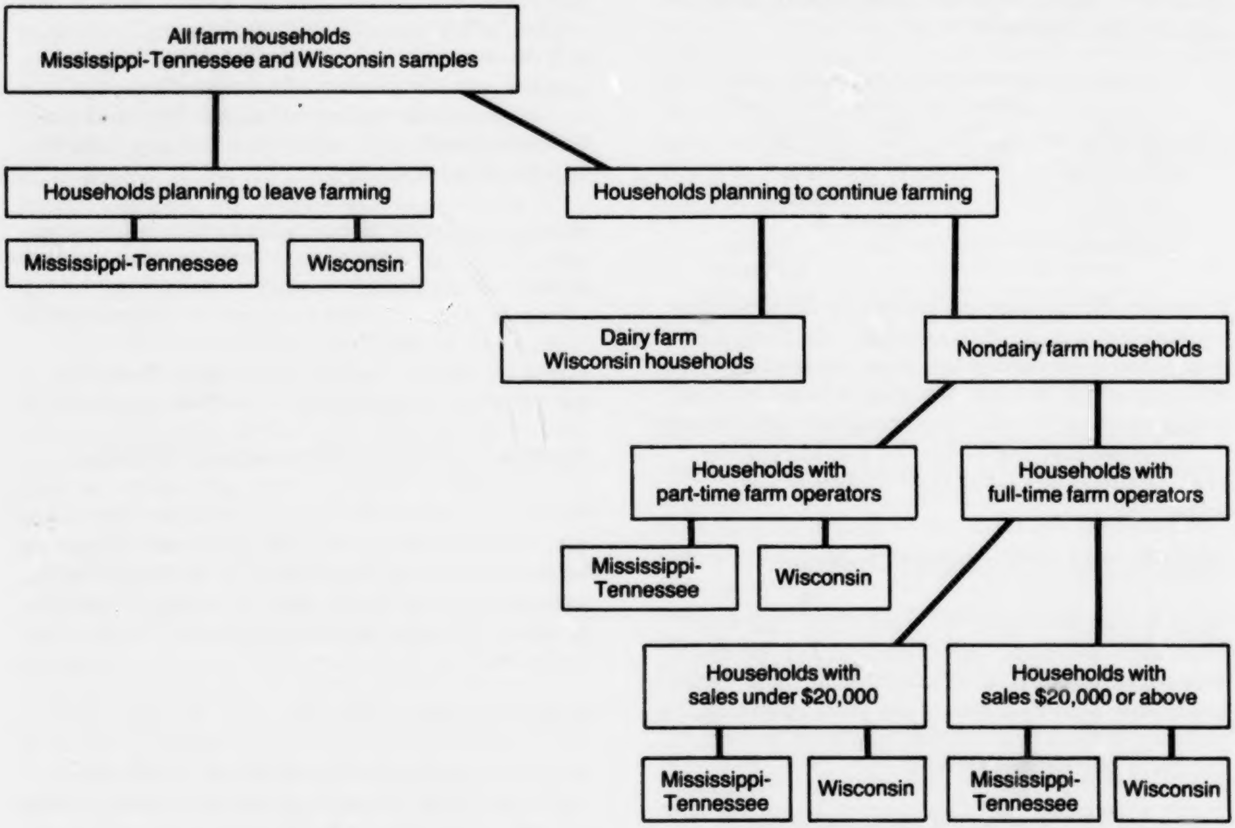
[7] Operators who worked at least 160 hours off-farm during the survey year are classified as "part-time." Those who worked fewer than 160 hours off-farm during the survey year are classified as "full-time."

[8] Differences among household types are documented in "Farm Viability: Results of the USDA Family Farm Surveys," by Priscilla Salant, Melinda Smale, and William Saupe, U.S. Dept. of Agr., Econ. Res. Serv., forthcoming.

[9] Two-tailed difference-of-means tests were conducted at the 0.05 significance level. In the text, stated differences reflect the results of two-tailed statistical tests. Statements of relative magnitude do not reflect statistical tests because there was no *a priori* justification for one-tailed tests.

Figure 3

Selection of Farm Household Groups



Households with Part-Time Operators

Part-time farmers were defined as operators who worked off-farm at least 4 weeks per year. Financial and farm-size characteristics of part-time farmers were comparable between the two survey areas. Households in the Wisconsin area had an average net worth of $166,174 by the survey year, with a mean debt-asset ratio of 0.18. Households in the Mississippi-Tennessee area had an average net worth of $145,718 and a mean debt-asset ratio of 0.13. Farms in both survey sites were relatively small in terms of sales and acreage.

Although their high cash operating expenses contributed to negative net farm earnings, Wisconsin households received more off-farm employment and unearned income than those in the Mississippi-Tennessee area. On average, households with part-time operators received total income of $27,495 in Wisconsin and $23,072 in the Mississippi-Tennessee area. Over 80 percent of household income in both areas came from nonfarm sources. Less than 20 percent of all households with part-time operators had viability ratios under 1.0.

Table 1—Selected characteristics of nine farm household groups, 8-county Wisconsin area and 29-county Mississippi-Tennessee area

Item[1]	Unit	Dairy farmers	Part-time farmers		Full-time farmers				Farm exit	
					Sales under $20,000		Sales $20,000 or above			
		Wisconsin	Wisconsin	Mississippi-Tennessee	Wisconsin	Mississippi-Tennessee	Wisconsin	Mississippi-Tennessee	Wisconsin	Mississippi Tennessee
Farm households represented	Number	6,850	1,665	5,115	715	2,130	835	2,155	2,175	1,680
Sample households	do.	296	72	445	31	212	36	202	94	167
Human resource:										
Operator, age	Year	44.1	50.1*	47.3*	64.7	62.5	47.3	46.8	60.1*	63.2*
School completed	do.	11.6	12.3	11.6	9.7	8.7	11.5	11.7	9.9*	9.1*
Farming experience	do.	17.6	17.9	17.7	35.1	30.3	19.7	20.5	30.6	32.0
Spouse, age	do.	40.7	46.4	44.4	58.6	59.5	45.1	44.6	56.0*	58.9*
School completed	do.	12.2	12.7*	11.7*	11.0*	9.9*	11.8	12.3	11.7*	10.5*
Farm business:										
Gross sales	Dollar	84,916	17,406	12,962	6,206	5,701	114,187	128,272	38,384*	10,431*
Cash operating expenses	do.	58,561	18,215*	9,359*	6,621	4,987	91,515	78,338	25,779*	7,712*
Milk sales per cow	do.	1,479	—	—	—	—	—	—	—	—
Crop acres	Number	191	87	102	62	60	347*	690*	118	85
Dairy cows	do.	45	—	—	—	—	—	—	—	—
Financial resources:										
Total assets	Dollar	368,991	201,773	167,615	214,301*	146,018*	565,354	502,572	274,511*	179,766*
Total debts	do.	95,930	35,599	21,897	5,134	8,121	129,560*	75,957*	33,784*	5,854*
Net worth	do.	273,061	166,174	145,718	209,167*	137,897*	435,794	426,615	240,727*	173,912*
Debt/asset	Ratio	.26	.18	.13	.02	.06	.23	.15	.12*	.03*
Income source:										
Net cash farm operating	Dollar	20,808	–35*	3,713*	–99	872	21,715*	45,152*	12,029*	2,578*
Off-farm employment	do.	4,154	24,262*	18,446*	4,171	2,870	2,765	4,162	6,017	4,352
Unearned	do.	3,214	3,268*	913*	10,794*	4,544*	7,837*	1,935*	7,037*	4,411*
Total household income	do.	28,176	27,495	23,072	14,866*	8,286*	32,317*	48,249*	25,083*	11,341*
Viability ratio:										
Ratio under 1.00	Percent	47	18	17	32	54	42	45	3	9

*Values for which null hypothesis that Mississippi-Tennessee and Wisconsin means are equal has been rejected by use of a two-tailed t-test with significance level of 0.05.

— = Not applicable.

[1] Variables defined in glossary.

Households with Full-Time Operators and Smaller Farms (Sales under $20,000)

In both survey areas, operators of smaller farms and their spouses were close to retirement age and had less than a high school education. Many of these older operators were debt-free; the average debt-asset ratio was 0.02 in Wisconsin and 0.06 in Mississippi-Tennessee.

Farm size, measured by gross sales and crop acreage, was comparable in the two survey areas. Households generated an average of about $6,000 in gross sales on slightly over 60 crop acres. The average value of assets and net worth were higher for Wisconsin households.

Unearned income represented 73 percent of total household income in Wisconsin and 55 percent in Mississippi-Tennessee. Thirty-two percent of smaller full-time farms in Wisconsin had viability ratios under 1.0, compared with 54 percent in Mississippi-Tennessee.

Households with Full-Time Operators and Larger Farms (Sales of $20,000 or Above)

In each survey area, full-time operators of larger farms averaged 47 years of age, had a high school education, and 20 years of operating experience. These farmers averaged gross sales of $114,187 in Wisconsin and $128,272 in the Mississippi-Tennessee site. On average, Wisconsin operators generated comparable gross sales with fewer crop acres.

Average total assets and net worth were statistically equivalent for larger full-time farmers in the two sites. The average debt level was higher among households in Wisconsin than among those in Mississippi-Tennessee.

On average, higher debt levels on Wisconsin operations may have contributed to lower net cash income from farming. Wisconsin households received a higher absolute level and a greater proportion of their income from unearned sources. Although average household income was higher in the Mississippi-Tennessee survey area, the percentage of households with viability ratios under 1.0 is similar for the two regions (45 percent in Mississippi-Tennessee and 42 percent in Wisconsin).

Farm Exit Households

Operators planning to leave farming were close to retirement age, and they averaged over 30 years of farming experience. Farm size measured in terms of both sales and assets averaged larger in Wisconsin than in the Mississippi-Tennessee area. Wisconsin farmers averaged gross sales of $38,384 in 1982. Mississippi-Tennessee farmers averaged sales of $10,431 in 1980.

Households in the Wisconsin area reported average assets of $274,511 and equity of $240,727, compared with assets of $179,766 and equity of $173,912 among households in the Mississippi-Tennessee area. As a group, Wisconsin households had a greater debt burden, with an average debt-asset ratio of 0.12. Farm exit households in the Mississippi-Tennessee site had an average debt-asset ratio of only 0.03.

Despite their higher operating expenses and debt levels, households in Wisconsin generated over four times the net cash farm income from farming of those in the Mississippi-Tennessee area. The average level of unearned income was also higher among Wisconsin households. Households in Wisconsin received 48 percent of their total income from farming. In contrast, net cash income from farming represented only 23 percent of total income for households in the Mississippi-Tennessee area. Three percent of farm exit households in Wisconsin and 9 percent of those in the Mississippi-Tennessee area had viability ratios under 1.0.

Regression Model

The data presented in table 1 reveal differences in the level and composition of resources among farm household types and regions. Some of these human, farm business, and financial resource characteristics are hypothesized to be associated with household viability. To examine the relationship of household characteristics to viability, we analyzed farm households by group through regression analysis.

Farm Business Variables

Farm size can be represented by a variety of physical and financial measures. Gross sales of agricultural products, a conventional measure of size, reflects the physical volume of farm output weighted by product price. Crop acreage is a measure of size for many enterprises based on crop production. The value of household assets represents the quantity of real estate, livestock, machinery, and other assets, weighted by their market prices. To express several size measures in a compact form, we used gross sales, crop acres, and total assets variables to construct a standardized size index for each household group.[10]

The net effect of these farm size factors on household viability may be either positive or negative for dairy, part-time, or full-time operations. Although a higher value of assets improves the farm household's potential for obtaining operating and farm investment loans, many families who chose to expand their operations through debt-financing now encounter financial problems. For farm exit households, whose future flow of earnings has been estimated from the value of net worth, off-farm employment, and transfer income, greater farm size is expected to bear a strong and positive relationship to household viability.

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[10] We constructed a standardized size index through principal components analysis for each household group. This index is a factor score with a unique value for each household in the group. The factor score is a weighted sum of the household's gross sales, crop acres, and total assets.

We also hypothesized that farm business efficiency (output per unit of input) is positively associated with viability. However, the survey data usually did not permit construction of tenable efficiency measures because of heterogeneous product types. In the case of Wisconsin dairy farmers, who share a homogenous product and similar input mix, we included a proxy in the analysis. The proxy, an index of gross sales per dollar of purchased input, measures how effectively the farmer converted physical units of inputs (weighted by price and aggregated) into physical units of product (similarly weighted and aggregated). The following analysis terms this variable "farm productivity."[11]

Financial Resource Variables

The financial structure of the household affects current income through debt-servicing requirements. If income is held constant, households with a high debt burden in relation to assets must use more of their current income to meet interest and principal payments, leaving less income for consumption needs and capital replacement. Farm families with a high debt-asset ratio and poor repayment history may be refused financing by credit institutions. In the short run, these families can meet principal payments by reducing living expenses or foregoing capital replacement. They may be obliged to liquidate productive assets in the long run. The debt-asset ratio for any household type is a measure of financial structure and of credit risk and is expected to relate negatively to viability.

Human Resource Variables

We also hypothesized that human resources are associated with household viability. Empirical measures of these resources include years of farming experience and formal education of the operator, hours of nonoperator (that is, spouse or other adult) labor devoted to farm activities, whether or not nonoperators worked off the farm, and number of children in the household under age 16.[12]

"Years of farm-operating experience" expresses the effects of additional farming expertise gained during the early, human capital investment years of the farm operation. At a lower level of experience, associated with younger operator age, the effect of additional skills and expertise on viability is hypothesized to be positive and of relatively large magnitude. Over time, an additional year of farming experience contributes less to farming expertise. At the same time, debts accumulated during the earlier phases of operation are gradually retired, reducing debt-servicing requirements. The effects of these factors in farming experience should relate quadratically to household viability.

The number of children under age 16 may be associated with greater consumption needs and lower off-farm earnings while families attend to child-rearing and home production. During the child-rearing years, adult family labor is allocated to home production activities that are not measured in either farm or off-farm income. The number of younger children should be negatively related to viability.

Operator education should affect household viability positively to the extent that it increases labor productivity. To the extent that education, first, has a greater effect on returns to nonfarm labor than to farm labor and, second, acts as an "entry card" to certain nonfarm jobs, we may expect to see the strongest relationship in the case of part-time farmers.

The spouse of the farm operator and other adult household members can contribute to household income through farm or off-farm activities. These factors are measured by hours of nonoperator onfarm labor and by a binary variable indicating whether or not nonoperator household members worked off-farm during the survey year. Higher levels of either farm or off-farm commitment should be associated with greater household viability.

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[11] To avoid estimation problems resulting from correlation between dependent and independent variables, we used an index of relative efficiency in place of "sales per dollar of purchased input."

[12] Although use of a continuous variable representing hours of off-farm work would have been conceptually preferable, we chose a binary variable to avoid estimation problems.

Specification

The regression model is specified as:

$$Y = \beta_o + \sum_{i=1}^{9} \beta_i X_i + \epsilon$$

where:

Y = Viability ratio,
X_1 = Size index,
X_2 = Debt-asset ratio,
X_3 = Farm productivity (dairy farms only),
X_4 = Years of operator education,
X_5 = Years of operator farming experience,
X_6 = $(X_5)^2$,
X_7 = Nonoperator off-farm labor (1 = yes, 0 = no off-farm work),
X_8 = Hours of nonoperator onfarm labor, and
X_9 = Number of children under age 16.

The viability ratio compares total earnings with total financial obligations for each household. Differences in the variables X_1-X_9 should relate significantly to observed variation in the viability ratio. We applied the regression model separately to households in each group, assuming that the relationship of household characteristics to the viability ratio differs by group.

Wisconsin Area Results

Table 2 shows regression results for households in the Wisconsin area. Household groups include dairy farm households, households with part-time operators, households with full-time operators and smaller farms (sales under $20,000), households with full-time operators and larger farms (sales above $20,000), and households planning to leave farming.

Dairy Farm Households

Among dairy farm households, variation in the debt-asset ratio, farm productivity, operator education, years of operating experience, the decision to work off-farm by the spouse or other household members, and the number of young children are associated with variation in the viability ratio. The average dairy farmer in the Wisconsin site is young in relation to operators of other household groups and has a high school education and 17 years of experience (table 1). For these operators, regression results suggest that additional years of education are related to greater household viability. Although the effect of onfarm employment of the spouse and other household members is not significant, off-farm work is associated positively with household viability. As expected, higher debt-asset levels are associated with lower viability. Variation in the farm size index is not significantly related to viability. For these farm families, who receive 75 percent of their total income from net farm earnings (table 1), greater farm productivity contributes positively to household viability.

Among dairy farmers, regression results indicate that the viability ratio is negatively related to operating experience through 19.5 years and is positively related after 19.5 years.[13] This relationship may reflect the combined effects of accumulated technical expertise and gradual retirement of farm debts, but it may be dominated by the financially difficult circumstances of younger farm entrants with large debt loads in relation to their farm income. The life-cycle of the farm family, measured as the number of children under age 16, is negatively associated with viability. During the child-rearing phase of the family life cycle, relatively more of the total adult effort is used for home production and less for off-farm work or farm production.

Households with Part-Time Operators

Households in this group received 88 percent of their total income from off-farm earnings (table 1). Among these households, the debt-asset ratio, farm size, and operator education are significantly associated with the level of the viability ratio. A higher debt-asset ratio influences viability negatively. Additional operator education, which enhances employment opportunities, is associated with greater household viability. Larger farm size, which may constrain the ability to allocate labor off-farm, is associated with lower household viability. The data

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[13] The first partial derivative of the function is zero at 19.5 years of operator experience.

Table 2—Farm household viability, by household group, 8-county Wisconsin area

Explanatory variable[1]	Coefficients[2]				
	Dairy	Part-time	Full-time		Exit
			Smaller	Larger	
Constant	0.689** (.369)	0.595 (.694)	3.245** (1.647)	1.257 (2.332)	3.850*** (1.272)
Size index	.042 (.049)	–.195** (.116)	–.385* (.129)	.081 (.309)	1.400*** (.203)
Debt-to-asset	–2.446*** (.235)	–1.398** (.740)	.629 (1.696)	–3.038** (1.583)	–4.727*** (1.429)
Farm productivity[3]	1.633*** (.164)	— —	— —	— —	— —
Operator education	.057*** (.024)	.088*** (.040)	.091 (.098)	.030 (.139)	.119* (.080)
Operator experience	–.039*** (.016)	.041 (.032)	–.121** (.068)	–.006 (.089)	–.012 (.044)
(Operator experience) squared	.001*** (.0004)	–.001* (.0006)	.001 (.001)	.001 (.001)	.00005 (.0007)
Nonoperator off-farm employment	.169** (.096)	.321 (.232)	.232 (.466)	1.107** (.625)	.092 (.387)
Nonoperator onfarm labor	.00002 (.00002)	–.00005 (.00007)	–.0003 (.0003)	–.0001 (.0001)	— —
Number of children under 16 years	–.108*** (.034)	–.082 (.086)	–1.049** (.589)	–.056 (.207)	–.133 (.241)
Number of observations	296	72	31	36	94
F	36.5	3.42	1.79	1.78	10.53
R^2	.52	.21	.17	.15	.42

— = Not applicable.

[1] Dependent variable is the viability ratio.

[2] Ordinary least squares estimates with standard errors in parentheses. Significance levels: 0.05***, 0.10**, and 0.15*.

[3] Measured for dairy farms only. Other groups were heterogeneous in terms of products and technology.

do not support the hypotheses that operator experience and nonoperator employment variables, as specified, are associated with viability.

Households with Full-Time Operators and Smaller Farms

Operators in this group were essentially debt free and near retirement age (table 1). The F-test for the group indicates that the joint effect of explanatory variables on the viability ratio is not significantly different from zero. Larger farm business size is associated with lower viability, suggesting that these smaller scale farm enterprises may suffer from production inefficiencies. All but two of the sample households in this group were debt-free, and differences in viability are not related to the debt-asset ratio. As in the case of dairy farmers, the number of children under age 16 is negatively associated with viability.

Households with Full-Time Operators and Larger Farms

Financial structure and nonoperator off-farm employment are associated with household viability among this group of households. The negative effect of the debt-asset ratio expresses financial obligations for both interest expenses and regular payments to retire debt. The positive effect of off-farm work by nonoperator adults indicates that even on larger farms, allocation of family labor to off-farm work can enhance viability. The separate effects of farm business size and other human resource variables, as specified, are not significant.

Farm Exit Households

The viability ratio for farm exit households expresses post-exit circumstances. Therefore, variables measuring farm productivity and onfarm labor hours of other adults in the family are not applicable to the analysis. In the Wisconsin area, the size of the farm operation has a large, positive effect on the viability of households planning to leave farming, and a higher debt-asset ratio has a large, negative effect. These results reflect the importance of net worth in determining the estimated future flow of income for exit farmers. With an average net worth of $240,000 and a mean age of 60 (table 1), this group is more representative of retiring farmers than of operators leaving the farm under financial duress. The positive effect of operator education may reflect the nonfarm employment alternatives available to the younger members of this exit group.

Mississippi-Tennessee Area Results

Table 3 shows regression results for households in the 29-county area of Mississippi-Tennessee. Household groups for this survey area include households with part-time operators, households with full-time operators and smaller farms (sales under $20,000), households with full-time operators and larger farms (sales of $20,000 or above), and households planning to leave farming.

Households with Part-Time Operators

The debt-asset ratio is negatively associated with viability among households in this group, as is the number of children under age 16. Higher levels of operator education positively influence viability, as does the presence of a nonoperator working off-farm. Similar effects of the debt-asset ratio and operator education were observed among households with part-time operators in the Wisconsin area. Years of experience as a farm operator is positively related to viability through about 15 years and negatively related after 15 years. This result may express the effect of advancing age (a correlated variable) on off-farm employment and wage rates.

Households with Full-Time Operators and Smaller Farms

As in Wisconsin, the F-test for this group indicates that the joint effect of the explanatory variables on viability is not significantly different from zero. Among the individual variables, only the debt-asset ratio (negatively related) and off-farm work by nonoperator adults (positively associated) are significant. Given the relatively low average income level among this group, it appears that nonfarm earnings by nonoperators are a key factor in enhancing viability.

Households with Full-Time Operators and Larger Farms

Among households in this group, only differences in farm size and the debt-asset ratio are associated with variation in household viability. If other factors are held constant, larger operations tend to have higher viability ratios, whereas households with higher debt-asset ratios tend to have lower ratios. Thus, the farm business appears to be the most important factor affecting viability. Changes in human resource factors, as specified, are not associated with variation in household viability.

Farm Exit Households

The viability of Mississippi-Tennessee households planning to leave farming is related to farm size, the debt-asset ratio, operator education, and nonoperator off-farm employment. (Similar relations between the explanatory variables and viability were observed in the Wisconsin area, except in the case of nonoperator off-farm employment.) The greater the size of operation (that is, the more assets available to generate a flow of asset income), the more viable the farm exit household will be. Conversely,

Table 3—Farm household viability, by household group, 29-county Mississippi-Tennessee area

Explanatory variable[1]	Coefficients[2]			
	Part-time	Full-time		Exit
		Smaller	Larger	
Constant	1.313*** (.299)	0.933*** (.319)	1.420** (.879)	1.412 (1.089)
Size index	-.072 (.062)	-.113 (.082)	.421*** (.150)	1.450*** (.230)
Debt-to-asset	-1.872*** (.346)	-.767** (.469)	-3.499*** (.634)	-3.412*** (1.262)
Operator education	.085*** (.018)	.012 (.021)	.056 (.056)	.308*** (.062)
Operator experience	.018 (.016)	-.006 (.017)	.017 (.037)	.036 (.059)
(Operator experience) squared	-.0006** (.0003)	.0002 (.0002)	-.00004 (.0007)	.0008 (.0009)
Nonoperator off-farm employment	-.573*** (.120)	.299** (.181)	.125 (.306)	1.018** (.526)
Nonoperator onfarm labor	-.0001 (.00009)	-.00004 (.0001)	-.00002 (.0001)	— —
Number of children under 16 years	-.314*** (.049)	-.057 (.080)	.091 (.135)	-.243 (.371)
Number of observations	445	212	202	167
F	18.32	1.46	5.76	12.99
R^2	.24	.02	.16	.34

— = Not applicable.

[1] Dependent variable is the viability ratio.

[2] Ordinary least squares estimates with standard errors in parentheses. Significance levels: 0.05***, 0.10**, and 0.15*.

the higher the debt-asset ratio, the less viable the household will be. Higher levels of operator education (which express enhanced off-farm employment alternatives), as well as off-farm employment by nonoperator household members, influence viability positively. Both relationships suggest that the ability to earn nonfarm income will improve the viability of households exiting from agriculture.

Implications

The regression results are generally consistent with hypothesized relationships for all groups except households with full-time operators and smaller farms in both study sites. The latter group and households planning to leave farming represent special cases.

Smaller, full-time farmers in each survey area worked off-farm less than the equivalent of 4 weeks during the survey year and planned to continue farming over the next 5 years. On average, they grossed only about $6,000 in farm product sales. The typical operator was near retirement age (63-65 years old), free of debt, and received the largest proportion of total income from transfers, rents, interest, and other unearned sources. Attributes other than those included in the model presented here may be associated with viability. The inadequacy of the model in explaining variation among these families underscores their uniqueness.

Thirty-two percent of the smaller, full-time farm households in Wisconsin and 54 percent of these households in the Mississippi-Tennessee site had viability ratios under 1.0, or an annual income insufficient to cover farm and personal financial obligations during the survey year. These farm families would benefit from programs designed to help them close unprofitable farm businesses and convert farm assets into a dependable flow of retirement income. Some of these families may need information about their eligibility for Social Security, Supplemental Security Income, and Medicare/Medicaid programs.

Changes in the capital gains aspects of tax policies and the development of institutions to facilitate the conversion of farm assets into a retirement income flow would improve their financial prospects. Such changes would also enhance the financial position of families planning to leave farming. In contrast to the smaller full-time farmers, only 6 percent of the farm exit households in the combined survey areas had viability ratios under 1.0. This percentage was higher in the Mississippi-Tennessee survey area, where both average unearned income and net worth are lower. Operators in these households also were older and less educated. For farm exit households, the results indicate that greater viability is associated with larger farm size, more farm assets, a lower debt-asset ratio, and off-farm employment by the spouse and other household members.

Other household groups planning to continue farming include Wisconsin dairy farmers, part-time farmers, and larger full-time farmers in both survey areas. Among these groups, the proportion of households with viability ratios under 1.0 is lowest for the part-time farmers (17 percent) in both survey areas. Almost 50 percent of dairy farmers have viability ratios less than 1.0. Among the full-time operators in both survey areas, slightly over 40 percent have ratios under 1.0. To continue operating the farm household under the year-of-survey organization, these families must either reschedule debts, forego capital replacement, or consume below the minimum level used in this analysis. Over the long run, farm-level adjustments will be necessary to sustain their operations.

Regression results provide evidence that the factors related to viability differ by farm household group. Farm size, measured by an index of gross sales, crop acreage, and the value of total assets, is associated positively with viability only for larger full-time farms in the Mississippi-Tennessee area and for farm exit households in both regions. The positive relationship of size to viability for farm exit households is explained by the importance of asset values in determining income flows after leaving farming. Among households planning to continue farming, results of the analysis suggest that farm growth strategies benefit only larger operations and only under particular conditions. For other groups in the sample, gains in returns from expansion may be offset by debt-servicing requirements or production inefficiencies. Greater farm size is associated with lower household viability among smaller full-time farmers and part-time farmers in the Wisconsin survey area.

A higher debt-asset ratio implies that a larger proportion of the annual income must be used to meet interest payments and payments toward loan retirement. The debt-asset ratio, a measure of the credit risk and financial structure of the farm household, is associated negatively with household viability for all household groups except the smaller full-time operations in Wisconsin. In that group, 29 of the 31 sample farms were debt free, and their debt-asset ratio was zero. Public initiatives to reduce interest rates, to guarantee farm loans, or to provide incentives for forgiving loans will affect the survival prospects for both full-time and part-time farmers during the adjustment to new product prices and interest rates. The effect on viability of a higher debt-asset ratio is greatest for larger full-time operations.

Years of operator education is associated positively with household viability among dairy farmers, part-time farmers, and exit farmers in both survey regions. Formal education affects household income by improving off-farm wage-earning potential. For part-time and exit farmers, a higher rate of off-farm earnings contributes both to current wage income and to the level of Social Security benefits available on retirement.

The positive and significant relationship between operator education and the viability ratio among dairy farmers may not express off-farm wage-earning capacity. Dairy farmers tend to work off-farm fewer hours than operators of other farm types, and education may contribute instead to the operator's farm management skills. However, this effect was not observable in the analysis of smaller and larger full-time farmers in either survey area.

Regression results support the hypothesis that, for dairy farmers, years of experience are related quadratically to household viability. Through 19.5 years of experience, an additional experience is related to lower viability. After 19.5 years of operation, additional experience is related to higher viability levels. This relationship may reflect the counteractive effects of cumulative farming expertise and the financial conditions at the time the farm business was established. Although relatively high interest and principal payments on debt are characteristic of the early farming years, the regression coefficient for this variable may reflect particular historical circumstances. Operators entering the dairy business in more recent years were confronted with greater initial capital outlays that may have required costly debt-financing.

For five household groups, off-farm work by nonoperator household members is associated with greater viability, whereas an additional hour worked onfarm has no observable effect with any household group. Nonoperator off-farm employment is associated positively with household viability for each of the five groups, except part-time farmers in the Mississippi-Tennessee area. The magnitude of the effect varies greatly among the groups. Nonoperator onfarm hours, however, are not associated positively with household viability for any of the sample groups. In recent years, increasing numbers of farm families have chosen to increase their off-farm labor commitment. These results imply that more farm families may benefit from re-evaluating their present allocation of farm and nonfarm labor.

This study expresses the life-cycle stage of the farm family by the number of children under age 16 in the household. This variable reflects the obligation of adult family members to home production, as opposed to farm production or off-farm employment opportunities. The value of home production has not been measured in the viability ratio. The relationship of the life-cycle stage to farm household viability is significant for three of the household groups. Where significant, the effect of additional children under age 16 is negative, as expected.

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Appendix: Glossary

Crop acres include all land in crops, orchards, vineyards, nursery and greenhouse products, cropland diverted under Federal program guidelines, and acres used for pasture or grazing that are suitable for crops without improvements.

Debt-to-asset is the ratio of total farm and personal debts to total farm and personal assets, as of January 1 of the survey year.

Estimated annual income from value of net worth is the yearly amount of income a household planning to leave farming can expect to realize from the disposition of farm assets. Farm exit households with nonland assets sufficient to cover all debts are assumed to either rent the farm or sell the farm on land contract, depending on the option they specified in the interview. In addition to income from the sale or rental of their land, these households are expected to receive a 10-percent return on investment of their nonland assets.

Rental income is calculated at 6 percent of the market value of land assets. Income from land contracts is based on a 20-year agreement with equal annual principal payments and 10-percent annual interest on the unpaid balance. We used Federal and State tax tables to estimate the after-tax income from land contract sales.

We assumed that households with debts exceeding the value of their nonland assets would liquidate the farm. To determine the net amount of money available for investment after liquidation, we subtracted both the value of all debts and the capital gains tax liability for the value of assets. Estimated annual income for households liquidating the farm is equal to 10 percent of after-tax earnings from the sale of the farm plus 10 percent of the value of remaining assets.

Estimated capital replacement costs were calculated at 10 percent of the value of all farm machinery, trucks, and cars.

Estimated minimum consumption is equal to the poverty threshold income level for the household, by household size and age of household head, as developed by the Bureau of the Census. For the purposes of this analysis, the household includes all individuals residing together at the time of the survey.

Estimated principal payments were calculated on the basis of the type of collateral under which individual loans were secured. Loans secured by real estate were assumed to have 20-year payback periods. Three-year payback periods were assumed for loans secured by personal property, and those secured by crop liens were assumed to have a 1-year payback period. If loans were not secured, the length of payback period was assigned according to the purpose of the loan: 20 years for real estate purchases, 3 years for production input purchases, and 2 years for household-related purchases. Annual payments were assumed constant over the life of the loan.

Estimated Social Security income was calculated for households in which either the spouse or the operator reached age 61 or over during the survey year. For persons at least 61 years of age at the time of the interview, the estimated Social Security payments were equal to their observed value. For persons who did not report benefits, we calculated estimates using Social Security Administration guidelines.

Estimated wage income was calculated on the basis of the age and off-farm employment experience of each household member. Persons over 64 years of age in the survey year were assumed to retire from off-farm work. Individuals between the ages of 50 and 64 were assumed to maintain the survey year level of off-farm work. Those under 50 years of age were assumed to begin working full-time off-farm when they left farming, whether or not they had worked off-farm in the past. For individuals who reported off-farm work in the survey year, the estimated wage rate was equal to the observed wage rate. For those who did not report off-farm work, the estimated wage income was equal to full-time earnings at the minimum wage rate.

Gross sales include all cash marketings of crops and livestock during the calendar year.

Cash income from farming is equal to the sum of gross sales plus farm-related income less cash operating expenses. Farm-related income includes receipts from custom work on other farms, gas tax refunds, patronage refunds, and Government grain storage programs.

Nonfarm earned income includes all household income from wage employment and net household income from self-employment in occupations unrelated to farming.

Nonoperator onfarm labor is equal to the annual hours of onfarm work by household members, excluding the farm operator.

Nonoperator off-farm labor is equal to the annual hours of work off-farm in nonfarm-related occupations by household members, excluding the farm operator. In the analyses, a dummy variable was used that was set equal to 1 if this variable was greater than zero, and to zero otherwise.

Off-farm employment income is equal to household income from wage and salary employment plus net income from nonfarm self-employment.

Other income includes public transfer payments, Social Security and private retirement income, rent, interest, and dividends.

Operator education is equal to the years of formal education of the farm operator.

Operator experience is equal to the operator's years of experience operating the survey farm or other farms.

Total household income is equal to the sum of cash income from farming plus off-farm employment income plus other income.

Transfer payments include pension and retirement income other than Social Security benefits, welfare and other public assistance, and unemployment insurance.

In Earlier Issues

Fingers were the first digital computers. The only really new thing about an electronic calculator is its fantastic speed. It does simple arithmetic literally at lightning speed. This places a premium on the development of such formal techniques as linear programming, input-output analysis, and the theory of games. These are high-powered analytical vehicles capable of using the speed.

Ronald L. Mighell and Burton L. French
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Optimization of Policy Goals in the Context of a Sector Model

By Nicole S. Ballenger and Roger D. Norton*

Abstract

This article investigates the possibilities of including policy choices directly into a sector model that simulates an economic equilibrium. It uses a mathematical programming framework because these models have wide applicability in agricultural sector analysis. The objective function is quadratic because the authors assume demand functions are linear. They formulate a policy choice model which they apply to Mexican agriculture.

Keywords

Policy modeling, mathematical programming, Mexican agriculture

Introduction

Incorporating a policy choice problem into a sector programming model directly is usually impossible because the sector model's objective function and constraint set are designed to simulate the equilibrium outcome of decentralized decisionmaking (*5*)[1]. Imposing a policy maximand on the model will destroy the simulating character of the outcome. Imposing policy constraints on the model will create a similar problem.

This article explores a special case in which the policy maximand and the market-simulating maximand coincide. They coincide when policymakers wish to maximize consumer plus producer surplus. Although the sum of surpluses is not a welfare measure in itself, Willig has shown that it can often be a good approximation of a true welfare measure (*13*).

The empirical problem formulated in this article is how to allocate a fixed Government budget to subsidies of several targeted crops in Mexico.[2] Given that the Mexican Government wishes to subsidize its agricultural sector to benefit both producers and consumers, a question arises about the most efficient allocation of crop subsidies. The analysis covers Mexico's eight principal crops: corn, wheat, sorghum, rice, soybeans, dry edible beans, safflower, and sesame. In analyzing the results, we give particular attention to the effects of policies on trade, because these crops have been assigned priority under recent Mexican programs aimed at attaining food self-sufficiency.

Methodology

Mathematical programming models have become progressively more sophisticated. The use of the programming framework is still limited, however, in terms of conducting systematic and comprehensive agricultural policy analyses. Although these models are useful in determining the impacts of specific policies, they are far less valuable in formulating complete statements of policy problems and in identifying "optimal" policy instruments.

The policy-cum-simulation problem is inherently a two-level maximization problem (*4*). A policy objective function is maximized subject to policy limits (such as budget constraints) *and* subject to maximization of the market-simulating objective function. This problem cannot be solved by normal mathematical programming algorithms; in fact, there is no procedure for obtaining the global joint maximum. However, local point optima can be found in some cases (*3*).

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[1] Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] We selected these crops because they might help achieve other objectives, such as food self-sufficiency, which are not explicitly stated in the model. If these other objectives are explicitly stated, then we must move from a single- to a dual-level programming framework to model the Mexican policy problem (*1*).

In view of these difficulties, the typical procedure for analyzing policy options is to solve the sector model (with market simulating maximand) repeatedly, under different values of policy *parameters*. The consequences of different policies can thereby be explored. The literature contains numerous examples of this procedure (*2, 7, 12*). The procedure clearly requires prior specification of potentially interesting policy options; it does not permit formal maximization of a policy objective function. Nevertheless, economists have conducted some fairly systematic explorations of the "policy-feasible space" in this way (*1, 6, 10*).

Thus, policies are generally treated as exogenous in the usual sector model framework. For example, demand or supply functions are shifted to reflect taxes or subsidies, or tariffs are added to world prices. After these policies are incorporated, the solution can be interpreted as a market equilibrium under Government intervention.

Our approach, however, differs somewhat because the model itself determines values of policy variables. The objective function is still the maximization of producer plus consumer surplus. But, because the objective function contains policy choice variables, its purpose is no longer only to describe market behavior. It now describes the market's reaction to a given allocation of subsidy funds, and it simultaneously evaluates alternative outcomes and allocates subsidies in a way that maximizes the surpluses. The problem is essentially a two-level problem (*3*) which is collapsed to one level in this special case. If the public- and private-sector problems were to diverge (for example, if the policy problem were to maximize employment rather than producer and consumer welfare), then the one-level approach would no longer be valid and a two-level model would apply.

The "optimal" crop subsidy program will be a function of the Government decision rule (that is, the maximization of the net sum of producer plus consumer welfare), the set of policy instruments available to policymakers; the size of the Government budget; and the behavior of the private sector in response to Government intervention (namely, the implicit or explicit supply and demand functions). Thus, the interaction of the public and private sectors is especially important when the policy problem is formulated.

We formulated this "optimal" subsidy model for the small-country case with fixed costs and linear demands as follows:

$$\text{Max} \sum_i (a_i x_i^c + \tfrac{1}{2} b_i x_i^{c\,2}) - \sum_i c_i x_i^p + \sum_i s_i x_i^p + \sum_i p_i^e x_i^e - \sum_i p_i^m x_i^m \tag{1}$$

Subject to:

$$R x^p \le \bar{r} \qquad [\lambda_j] \ j = 1,\ldots,M \text{ resources} \tag{2}$$

$$-x_i^p + x_i^c + x_i^e - x_i^m \le 0 \qquad [\pi_i] \ i = 1,\ldots,N \text{ crops} \tag{3}$$

$$\sum_i s_i x_i^p \le \bar{g} \qquad [\theta] \tag{4}$$

$$s_i \le \bar{s}_i \qquad [\phi_i] \ i = 1,\ldots,N \text{ crops} \tag{5}$$

The endogenous variables include:

x^c = a vector of quantities demanded;
x^p = a vector of quantities produced;
$p^c = a + bx^c$ = a vector of domestic consumer prices, where the matrix (b_i) is a diagonal matrix of demand slopes;
x^e = a vector of exports;
x^m = a vector of imports; and
s = a vector of output subsidies.

The exogenous variables include:

p^e = a vector of world prices for exports;
p^m = a vector of world prices for imports;
c = a vector of unit costs of production;
R = technology matrix, where r_{ji} is the quantity of the jth resource or input used to produce one unit of crop i;
$\bar{r}$ = a vector of resource constraints;
$\bar{g}$ = the Government budget constraint;
$\bar{s}$ = a vector of crop subsidy upper bounds; and
$\lambda, \pi, \theta, \phi$ = Lagrangian variables associated with the constraints.

Formulated in this manner, the model includes several new quadratic terms in the objective function and a quadratic budget constraint. Forming the Lagrangian results in the dual problem and the rules by which the optimal subsidy program is selected:

$$L = \sum_i \left(a_i x_i^c + \tfrac{1}{2} b_i {x_i^c}^2\right) - \sum_i c_i x_i^p + \sum_i s_i x_i^p$$
$$+ \sum_i p_i^e x_i^e - \sum_i p_i^m x_i^m + \sum_j \lambda_j \left(\bar{r}_j - \sum_i r_{ji} x_i^p\right)$$
$$+ \sum_i \pi_i \left(x_i^m - x_i^e - x_i^c + x_i^p\right) + \theta \left(\bar{g} - \sum_i s_i x_i^p\right)$$
$$+ \sum_i \phi_i \left(\bar{s}_i - s_i\right) \qquad (6)$$

The main first order conditions are:

$$\frac{\partial L}{\partial x_i^c} = a_i + b_i x_i^c - \pi_i \leq 0 \qquad i=1, \ldots, N \quad (7)$$

or:

$$a_i + b_i x_i^c = \pi_i \qquad \text{for } x_i^c > 0$$

$$\frac{\partial L}{\partial x_i^p} = - c_i + s_i - \sum_j \lambda_j r_{ji} + \pi_i$$
$$- \theta s_i \leq 0 \qquad i=1, \ldots, N \quad (8)$$

or:

$$\pi_i = c_i + \sum_j \lambda_j r_{ji} + \theta s_i - s_i \quad \text{for } x_i^p > 0$$

$$\begin{bmatrix}\text{Shadow}\\ \text{price}\end{bmatrix} = \begin{bmatrix}\text{marginal}\\ \text{cost}\\ \text{of}\\ \text{production}\end{bmatrix} + \begin{bmatrix}\text{marginal}\\ \text{cost of}\\ \text{resource}\\ \text{use}\end{bmatrix} + \begin{bmatrix}\text{implicit cost}\\ \text{of budget}\\ \text{restriction}\end{bmatrix} - \begin{bmatrix}\text{output}\\ \text{subsidy}\end{bmatrix}$$

The first equilibrium condition states that, for each commodity, the implicit valuation, or shadow price, equals the market price. This is the usual equilibrium condition. The second first-order condition states that, for each commodity, the shadow price equals the marginal cost of production plus the implicit marginal cost of resource use plus the shadow price of the budgetary restriction minus the value of the crop subsidy. In other words, the price can now be less than marginal cost, by the amount of the subsidy, adjusted for the opportunity cost of budgetary funds.

Thus, the presence of policy variables in the model is reflected in the second first-order condition. Equilibrium prices are modified by the subsidies and the shadow value of the Government budget constraint. The figure depicts an output subsidy for a single commodity and its impact on the equilibrium price.

In the figure, q^o is the unsubsidized market equilibrium quantity, and q^s is the quantity when a subsidy s is in effect. The price symbols are: p^p = producer price, p^o = unsubsidized market price, and p^c = consumer price.

The figure is a conventional diagram of market equilibrium under a subsidy with one exception: the difference $(p^p - p^c)$ is no longer equal to the nominal subsidy, but rather to the true subsidy, taking into account the opportunity cost of Government funds. Relating the figure to equations (7) and (8), we have:

$$p^p - p^c = s(1 - \theta) \qquad (9)$$

where the subscript i has been dropped for convenience.

Equation (9) follows because equation (7) says that $\pi_i = p_i^c$ and equation (8) says that $\pi_i = p_i^p - s(1 - \theta)$.

Application to Mexican Agriculture

The sector model used for this research is described in detail in (*1*).[3] It was adapted from the World Bank's model of Mexican agriculture (CHAC) (*11*).

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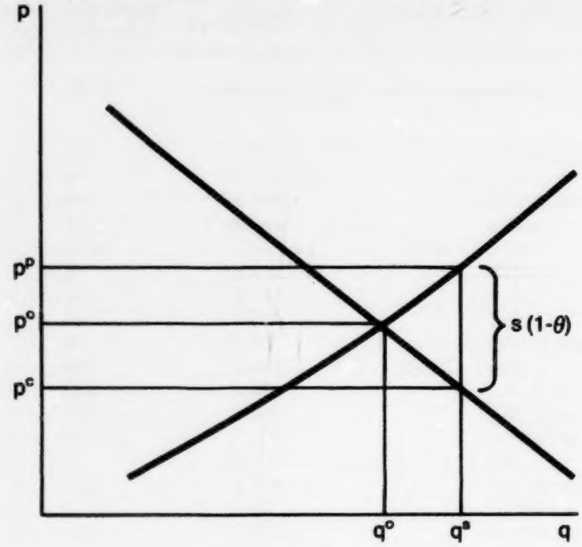
[3] The development of the technical coefficients and demand parameters for the original 1968 CHAC model is well-documented (*11*). The technical coefficients and resource constraints were updated to 1980 for this research based primarily on aggregate trends. Price elasticities of demand were assumed fairly stable over time. Income elasticities were derived from several sources (*1*).

Modified Equilibrium under Subsidies



The model's base solutions were good representations of actual supply and demand in Mexican agriculture in both 1968 and 1980. The base variants were modified subsequently to form the optimal subsidy version.

Whereas the original CHAC model was expressed in a linear programming format through a linear approximation procedure (*11*), the quadratic terms of our model have not been approximated. The model was solved with MINOS, a mathematical programming algorithm that uses a reduced gradient method for solving large-scale problems with nonlinearities in the objective function and/or the constraint set (*9*).

In modifying the original model, one needs two kinds of parameters: the total subsidy budget available ($\bar{g}$ in equation (4)) and the upper limits on subsidy rates by crop ($\bar{s}_i$ in equation (5)). We arbitrarily varied the values of these parameters in different solutions. We used three sets of illustrative values, which were not unrealistic for Mexican agriculture and policy in 1980 to define the following three main alternative solutions:

Case	Total subsidy budget	Upper bounds on crop subsidies
	Billion pesos	
1	25	1,000 pesos/ton[1]
2	25	40 percent of equilibrium prices
3	35	40 percent of equilibrium prices

[1] At 1980 prices, the 1,000-peso subsidy limit represented the following percentage subsidies of base-year prices: sorghum, 29; corn, 28; paddy rice, 27; wheat, 23; soybeans, 16; safflower, 13; beans, 9; and sesame, 5.

Tables 1-6 present the three alternative solutions. In case 1, the model chose seven of eight targeted crops–rice, safflower, dry beans, sesame, corn, sorghum, and wheat—to subsidize at the upper subsidy limit. Total subsidies to the three most important targeted crops—corn, sorghum, and wheat—are clearly the largest; therefore, they make the largest contributions to the value of the objective function. Tables 1 and 2 also show that allocating subsidies to these three crops increases their total supplies. Corn output increases 13 percent over the equilibrium solution with no subsidies; sorghum output increases 4 percent; and wheat output increases 14 percent. However, output decreases for the other four subsidized crops. Both rice and safflower output decline 5 percent; dry edible bean output declines 6 percent; and sesame output falls 37 percent. Sesame exports also decline 40 percent. These declines occur because the crop substitution effects are stronger than the output effects of the subsidies.

The supplies of alfalfa, sugarcane, barley, and cotton, and of nontargeted crops not eligible for subsidies decline significantly in absolute terms. Small absolute declines, but large percentage reductions, are indicated for minor crops such as lima beans (–15 percent) and flaxseed (–62 percent). Declines in total output of important export crops (tomatoes, melons, and vegetables) range from only 1 percent to 6 percent;[4] strawberry output declines slightly more (10 percent).

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[4] We assume that Mexico is a price-taker in all foreign commodity markets. This assumption is unrealistic in the case of most fresh vegetable and fruit trade, especially in the winter months when Mexico's production competes with Florida's production for the U.S. market. Other research based on CHAC focuses on the fresh vegetable- and fruit-producing regions of Mexico and relaxes the small-country assumption (*12*).

Table 1—Case 1: Commodity impacts of subsidy program[1]

Crop	Subsidies: Solution	Subsidies: Upper bound	Consumption	Exports	Imports	Production	Change in production from base solution[2]
	Pesos per ton		*1,000 tons*				*Percent*
Garlic			47.3	15.0		62.3	–1
Alfalfa			17,033.0			17,033.0	–6
Cotton			1,814.4	175.0		1,989.4	–4
Rice	1,000	1,000	606.8			606.8	–5
Sugarcane			13,926.2		400.0	13,526.2	–12
Squash			224.3			222.43	–2
Safflower	1,000	1,000	411.0			411.0	–5
Peanuts			166.4			166.4	–6
Onions			205.7	100.0		305.7	–1
Barley			650.7		200.0	450.7	–22
Dry chili			30.3	5.0		35.3	NC
Green chili			224.4	20.0		244.4	NC
Strawberries			161.4	60.0		224.1	–10
Beans	1,000	1,000	960.2			960.2	–6
Chick peas			347.5	100.0		447.5	NC
Lima beans			50.4			50.4	–15
Tomatoes			902.7	355.0		1,257.7	–1
Sesame	1,000	1,000	75.0	60.6		135.6	–37
Flaxseed			21.3		17.0	4.3	–62
Corn	1,000	1,000	9,840.4		242.6	9,597.8	13
Cantaloup			295.4	100.0		395.4	–5
Potatoes			745.4			745.4	–1
Cucumber			51.2	150.0		201.1	NC
Watermelon			615.7	100.0		715.7	–6
Sorghum	1,000	1,000	4,344.8			4,344.8	4
Soybeans	0	1,000	557.4		557.4	0	NC
Wheat	1,000	1,000	3,769.6			3,769.6	14

Blanks indicate not applicable. NC = No change. [1]Total available budget is 25 billion pesos. Individual subsidies limited to 1,000 pesos per ton. [2]Base model solution is the equilibrium solution with no subsidies.

Table 2—Case 1: Policy impacts of subsidy program[1]

Item	Unit	Amount	Change from base[2]
			Percent
Budget	10 million pesos	1,929.8	
Objective	do.	42,012.7	5.0
Exports	do.	1,399.0	5.0
Imports	do.	547.8	–50.0
Net trade	do.	851.2	120.0
Employment	1,000 work years	2,471.8	.6
Food grains	1,000 tons	13,367.4	13.5
Consumer surplus	10 million pesos	28,174.4	–9.0
Sector income	do.	13,982.6	51.0

Blanks indicate not applicable. NC = no change. [1]Total available budget is 25 billion pesos. Individual subsidies limited to 1,000 per ton. [2]Base model solution is the equilibrium solution with no subsidies.

Our conclusion is that important crop substitution occurs in Mexico among crops in the basic grain and oilseed group. Substitution between crops in this group and most major export crops is less important. Furthermore, the fact that production of some subsidized crops declines highlights the importance of considering the price ratios among targeted crops (as well as between targeted and nontargeted crops) when one formulates a crop subsidy program. In other words, if a goal of this subsidy program had been to stimulate output of all targeted crops, as was the case for the Sistema Alimentario Mexicano (SAM) program, the desired objectives would clearly not have been met.

Tables 3 and 4 present the results when the total budget constraint is again 25 billion pesos, but

Table 3—Case 2: Commodity impacts of subsidy program[1]

Crop	Subsidies		Consumption	Exports	Imports	Production	Change in production from base solution[2]
	Solution	Upper bound					
	Pesos per ton		*1,000 tons*				*Percent*
Garlic			47.8	15.0		62.8	NC
Alfalfa			18,083.9			18,083.9	NC
Cotton			1,892.3	175.0		2,067.3	NC
Rice	1,464	1,464	636.2			636.2	NC
Sugarcane			15,723.4		400.0	15,323.4	NC
Squash			227.8			227.8	NC
Safflower	0	3,123	432.5			432.5	NC
Peanuts			181.6			181.6	NC
Onions			209.1	100.0		309.1	NC
Barley			691.3		115.7	575.6	NC
Dry chili			30.4	5.0		35.4	NC
Green chili			225.2	20.0		245.2	NC
Strawberries			189.2	60.0		249.2	NC
Beans	1,279	4,349	1,025.4			1,025.4	NC
Chick peas			347.5	100.0		447.5	NC
Lima beans			59.5			59.5	NC
Tomatoes			918.9	355.0		1,273.9	NC
Sesame	0	7,436	115.4	100.0		215.4	NC
Flaxseed			28.2		17.0	11.2	NC
Corn	1,412	1,412	9,840.4		1,356.3	8,484.1	NC
Cantaloup			318.2	100.0		418.2	NC
Potatoes			752.0			752.0	NC
Cucumber			52.0	150.0		202.0	NC
Watermelon			658.6	100.0		758.6	NC
Sorghum	1,357	1,357	4,163.0			4,163.0	NC
Soybeans	0	2,537	557.4		557.4	0	NC
Wheat	1,777	1,777	3,714.2		418.9	3,295.3	NC

Blanks indicate not applicable. NC = No change. [1]Total available budget is 25 billion pesos. Individual subsidies limited to 40 percent of equilibrium prices. [2]Base model solution is the equilibrium solution with no subsidies.

Table 4—Case 2: Policy impacts of subsidy program[1]

Item	Unit	Amount	Change from base[2]
			Percent
Budget	10 million pesos	2,500	
Objective	do.	42,655	6.2
Exports	do.	1,479.2	NC
Imports	do.	1,091.8	NC
Net trade	do.	387.4	NC
Employment	1,000 work years	2,456.5	NC
Food grains	1,000 tons	11,779.4	NC
Consumer surplus	10 million pesos	31,023.7	NC
Sector income	do.	11,774.6	27.0

Blanks indicate not applicable. NC = no change. [1]Total available budget is 25 billion pesos. Individual subsidies limited to 40 percent of equilibrium prices. [2]Base model solution is the equilibrium solution with no subsidies.

when individual crop subsidies are limited to 40 percent of the current market price. (For example, the subsidy limit on corn is 1,412 pesos per ton, which is 40 percent of the equilibrium price generated with the sector model in the absence of Government intervention.) The optimal allocation of the budget is to subsidies of corn, sorghum, wheat, and rice (which are subsidized at the upper limit) and to dry beans (which are subsidized below the upper limit). However, soybeans, sunflower, and sesame are not subsidized. This solution makes it clear that when the subsidy limits are raised, it is optimal to specialize the subsidy policy and confine it to fewer crops. (The objective function's value is higher in case 2 than in case 1.) Byproducts of that specialization are lower employment and lower net imports.

Table 5—Case 3: Commodity impacts of subsidy program[1]

Crop	Subsidies: Solution	Subsidies: Upper bound	Consumption	Exports	Imports	Production	Change in production from base solution[2]
	Pesos per ton		*1,000 tons*				*Percent*
Garlic			47.2	15.0		62.2	-1
Alfalfa			16,029.0			16,029.0	-11
Cotton			1,745.2	175.0		1,920.2	-7
Rice	1,464	1,464	612.8			612.8	-4
Sugarcane			13,651.6		400.0	13,251.6	-14
Squash			222.8			222.8	-2
Safflower	3,123	3,123	437.5			437.5	1.1
Peanuts			160.1			160.1	-12
Onions			204.8	100.0		304.8	-1
Barley			638.0		200.0	438.0	-24
Dry chili			30.2	5.0		35.2	-1
Green chili			224.1	20.0		244.1	NC
Strawberries			161.1	60.0		221.1	-11
Beans	4,349	4,349	1,029.0			1,029.0	.35
Chick peas			347.5	100.0		447.5	NC
Lima beans			49.6			49.6	-17
Tomatoes			889.2	355.0		1,254.2	-2
Sesame	7,436	7,436	144.1	100.0		244.1	13
Flaxseed			17.0		17.0		-100
Corn	1,412	1,412	9,840.4		439.8	9,400.6	11
Cantaloup			287.0	100.0		387.0	-7
Potatoes			737.7			737.7	-2
Cucumber			50.4	150.0		200.4	-1
Watermelon			607.9	100.0		707.9	-7
Sorghum	1,357	1,357	4,399.7			4,399.7	6
Soybeans	0	2,537	557.4		557.4	0	NC
Wheat	1,777	1,777	3,714.2		61.3	3,652.9	10.9

Blanks indicate not applicable. NC = No change. [1]Total available budget is 35 billion pesos. Individual subsidies limited to 40 percent of equilibrium prices. [2]Base model solution is the equilibrium solution with no subsidies.

Table 6—Case 3: Policy impacts of subsidy program[1]

Item	Unit	Amount	Change from base[2]
			Percent
Budget	10 million pesos	3,315.6	
Objective	do.	43,370.4	8.0
Exports	do.	1,479.2	NC
Imports	do.	644.7	-41.0
Net trade	do.	834.5	115.0
Employment	1,000 work years	2,462.4	.2
Food grains	1,000 tons	13,053.5	10.8
Consumer surplus	10 million pesos	26,566.0	-14.0
Sector income	do.	16,948.3	83.0

Blanks indicate not applicable. NC = no change. [1]Total available budget is 35 billion pesos. Individual subsidies limited to 40 percent of equilibrium prices. [2]Base model solution is the equilibrium solution with no subsidies.

Tables 5 and 6 show that when the budget constraint is increased to 35 billion pesos (and individual subsidy constraints remain at 40 percent of market value), it is possible to include all targeted crops, except soybeans, in the subsidy program. It also becomes "optimal" to increase production of all subsidized crops, except rice, at the expense of production of nontargeted crops. Again, the most important substitutes are alfalfa, sugarcane, barley, and cotton, which register the largest absolute declines. There are important percentage shifts from lima beans, flaxseed, strawberries, and peanuts. In this case, too, the impact on other export crops is marginal; production decreases 1-6 percent.

In all three cases, the subsidy expenditures reallocate welfare between consumers and producers, and they benefit producers. The apparent cause is that supplies are reduced for many more crops than they are increased. With demand functions that are generally price-inelastic, coupled with import restrictions, this effect raises producer incomes and lowers consumer welfare. Thus, the optimal subsidy programs lead to price and quantity adjustments that bring about a higher level of the sum of surpluses, but lower aggregate consumer welfare. (This result does not occur for all crops individually.) This finding may suggest that maximization of the sum of surpluses, with no distributional weights, may not be the goal that most policymakers would prefer.

Implications

Some tentative policy-oriented conclusions emerge from our analysis:

1. Maintaining relative price ratios among crops targeted for self-sufficiency is important if supplies of all targeted crops are to increase; otherwise, substitution in the production of these crops can decrease the output of some of them.

2. Programs designed to subsidize the producers of this targeted set of basic commodities appear to have positive effects on most goals of Mexican policymakers, which include increasing employment, food grain production, and net foreign exchange earnings (because import cost savings outweigh lost export earnings). But, these programs have net negative impacts on total consumer surplus. (This analysis does not tell us how different consumer groups are affected.)

3. Larger allocations of public funds to subsidy programs, although clearly able to generate additional sector income, do not necessarily imply additional benefits in terms of other Government goals. For example, the 33-billion-peso subsidy program (tables 5 and 6) sets off a chain of crop substitution effects which had smaller positive employment impacts than the 19-billion-peso program (tables 1 and 2). Thus, one policy goal, such as increasing producer income, can be inconsistent with another, such as generating additional farm employment.

Furthermore, the analysis suggests a number of implications for U.S.-Mexican trade and competition:

1. Output price subsidies for the targeted crops, of the magnitude considered in this study, appear to have little impact on the supply and export of many fresh horticultural products. Cotton and sesame are the Mexican export crops for which substitution with grains is most important. Thus, Mexico's role in world cotton markets would continue to diminish under this policy scenario.

2. Mexican price policies considered here would reduce grain and oilseed imports, at least in the short run. However, grain imports would not be eliminated or even dramatically reduced by the use of these policy instruments alone.

3. Because of production substitution between food (corn and wheat) and feed grains, the relative prices of subsidized crops in Mexico could have important implications for the composition of grain and other basic commodity imports.

Finally, this analysis has demonstrated that there are workable opportunities for policy analysis with sector programming models that agricultural economists have barely explored. Our analysis strongly suggests, however, that when multiple crops are involved in the setting of policies, one cannot predict *a priori* the net effects of the overall policy package on some national economic goals. Hence, a detailed numerical analysis is necessary for a full exploration of policy consequences.

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Research Review

The Growth and Structure of International Trade Since the Second World War

Lyndon Moore. Totowa, NJ: Barnes & Noble Books,
1985, 393 pp., $34.95.

Reviewed by Stephen W. Hiemstra*

If everyone is an economist, then since 1980 every economist has become a trade economist. Changes in the international economy these past 5 years—economic recession, voluntary export restraints on various consumer goods, and financial distress—have profoundly affected everyone. Economists accordingly need to review their assumptions about how the world works. This need brought about Lyndon Moore's book, *The Growth and Structure of International Trade Since the Second World War.*

Moore's objective is to analyze the growth and composition of international trade since the war (pp. 4-5). She pursues this objective in three major sections. The first section reviews the history of agricultural, trade, commercial, and financial policies and the institutions set up to implement them. The second summarizes trade theory. The third section analyzes trade in agricultural commodities, fuels, textiles and clothing, and automobiles. Analysis of the effects of protectionism on employment and economic growth is an important theme throughout the book (pp. 3-4). .

In developing this theme, Moore sees a conflict between the stabilization and growth objectives pursued in public policies (pp. 3-4). Stabilization objectives pursued in macroeconomic and commercial trade policies are designed to maintain full employment. Growth objectives pursued in market structure and free trade policies serve to maximize the benefits of the specialization permitted by participation in the world market. Although these objectives are compatible over the long term, workers must often be retrained and seek new jobs to achieve the level of specialization necessary to compete in world markets in the short run. A tension between these objectives therefore emerges, suggesting that the gains from trade are as unequally distributed as resource endowments (p. 367).

Although the book is encyclopedic in its scope, Moore did not intend to write a textbook. Rather, she states in the preface she wrote the book to present trade patterns, history, and theory to policymakers. Viewed against this objective, she succeeds. The book presents simply and concisely the basic information generated by economic research over the years on trade problems. It accordingly best meets the need of the policymaker who is not by training an economist.

Although trade economists may often need to widen the scope of their reading, some may find this book lengthy and inconclusive. In analyzing the observation that major traders have begun to question the merits of free trade, for example, Moore makes only passing reference to the complaints of developing countries about the changing terms of trade (p. 367). Other hypotheses which might follow from her analysis—a slowing of the rate of technological advance or a slower growth rate as a consequence of adjustment to an already widened world market—are not considered. The book, therefore, falls short of its potential. Notwithstanding, most economists would benefit from reading the chapters on effects of technological change and foreign investment on trade.

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*The reviewer is an agricultural economist with the International Economics Division, ERS.

American Journal of Agricultural Economics

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Articles: Caves and Peterson, "Cooperatives' Tax 'Advantages'"; Sexton, "Formation of Cooperatives: A Game Theoretic Approach with Implications for Cooperative Finance, Decision Making, and Stability"; Beilock, Garrod, and Miklius, "Freight Charge Variations in Truck Transport Markets: Price Discrimination or Competitive Pricing?"; Bryant, "Portfolio Analysis of Poor Rural Wage-Working Families' Assets and Debts"; Torok and Huffman, "U. S.-Mexican Trade in Winter Vegetables and Illegal Immigration"; Lichtenberg and Zilberman, "Econometrics of Damage Control: Why Specification Matters"; Moffitt, Farnsworth, Zavaleta, and Kogan, "Economic Impact of Public Pest Information: Soybean Insect Forecasts in Illinois"; Smith, Desvousges, and Fisher, "Comparison of Direct and Indirect Methods for Estimating Environmental Benefits"; Caulkins, Bishop, and Bouwes, "The Travel Cost Model for Lake Recreation"; plus other articles, Comments, Replies, and Book Reviews.

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In This Issue

"Let the data speak for themselves." Both articles in this issue of *Agricultural Economics Research* address areas of research and analysis where this seemingly self-evident and noncontroversial statement is neither.

The first article, by Johnson and Baum, is best described as a statement of the current status of the continuing effort to develop and report a measure of U.S. farmers' income that accurately reflects the economic well-being in the farm sector. The U.S. Department of Agriculture (USDA) has been annually reporting farm income since 1924, and the series has been criticized probably since that year, as irrelevant, conceptually obsolete, and based on inadequate data.

USDA has not ignored the criticisms, but its efforts to address perceived problems have been complicated by the widely varying types and sizes of American farms, fairly rapid technological and structural change on these farms, and widely varying needs for and uses of farm income estimates. The agricultural economics profession has made many contributions to the ongoing review and development of the accounts over the years. A complete list of contributors would be too lengthy for this column, but a list of recent noteworthy intellectual and conceptual contributors within USDA would be headed by Eldon Weeks and outside by former President James Bonnen of the American Agricultural Economics Association.

USDA's ability to respond to suggested conceptual improvement has often been constrained by the unavailability of appropriate data. Johnson and Baum report on a major USDA effort to address this problem with an annual probability-based survey that uses integrated replicate sampling to obtain the necessary information. This change is important in the ongoing development of the farm income accounts, but is one in which users of farm income statistics have a large stake. In the continuing effort to enhance the credibility of this much maligned, but widely used, economic series, has this shift to a greater reliance on a single annual survey been a successful step? Readers will have to answer that for themselves.

The second article, by Orden, presents an estimation technique, vector autoregression (VAR), which begins by selecting a set of variables perceived as relevant to an economic issue under investigation. No variable is assumed to be exogenous *a priori*, and no variable is excluded from the autoregressive equation for any variable. This "let the data speak for themselves" approach to economic analysis has its supporters; yet, it is criticized by more structurally oriented modelers. Aware of this controversy, Orden guides the reader through the development of his VAR model, highlighting both pitfalls and points of strength. He discusses and interprets his model and presents impulse response functions from the model. The article addresses all the enticingly relevant questions about agricultural-macroeconomic linkages. Again, I ask: Was this journey successful? Have the data spoken convincingly?

Gerald Schluter

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Whole Farm Survey Data for Economic Indicators and Performance Measures

By James Johnson and Kenneth Baum*

Abstract

The aggregate economic indicators and statistical series published by the U.S. Department of Agriculture provide insufficient information for decisionmakers requesting disaggregated analyses of farm industries, farm types, or farm sizes. However, this information can be obtained through the annual probability-based Farm Costs and Returns Survey, which uses integrated replicate sampling.

Keywords

Economic indicators, Farm Costs and Returns Survey

INTRODUCTION

Users of agricultural data have become accustomed to a long history of published aggregate agricultural statistics. The Bureau of the Census, through the quinquennial *Census of Agriculture*, and the U.S. Department of Agriculture (USDA), through periodic surveys conducted by the National Agricultural Statistics Service (NASS)[1], have provided most aggregate farm sector data on the number of farms, the characteristics of farms and their operators, land use, commodity production, disposition and value, inventories, certain purchased inputs and other resource use, prices paid and received, and limited data on labor hours and wages (*2*).[2]

Although a variety of primary and secondary data series is available for economic analysis, the agricultural data base continues to contain major inadequacies. Little attention has been given to "our . . . investment in the conceptualization of agricultural data systems and to developing the entirely new systems of data needed to contend with problems of a rapidly changing economy and way of life" (*1*). The technical, financial, and managerial organization of farming is undergoing dramatic changes. Yet, the economic data base for agriculture remains focused largely on the concept of a homogeneous farming sector. Information about the economic performance and well-being of different types and sizes of farms and other distributional issues may, therefore, not be reliable when derived from aggregate statistics (*13*).

A second, more practical problem is the lack of appropriate data to implement current aggregate economic indicator concepts and distributional indicators either now developed or under development. For example, a large number of the components of the farm income and balance sheet statistics published by the Economic Research Service (ERS) are benchmarked to socioeconomic data collected through the *Census of Agriculture* and specialized Census followup surveys, many of which have been discontinued. Thus, portions of our agricultural economic statistics series have been either without a benchmark data source, such as off-farm income, or with a benchmark that, at best, will soon be more than a decade old.

Two important issues relate to our inability to fully use survey data to develop and improve research related to the well-being and performance of agricultural subsectors. First, although existing published data are useful, even critical, to most economic analyses, these cross-tabulations are often inadequate to meet specialized analytical needs or to create new or nontraditional economic indicators. This inadequacy occurs because many of the policy or research problems to be addressed focus on microeconomic issues and require data that focus on subsets of the farm-sector population with particular characteristics. And, although data are published for major farm subsectors and by major farm characteristics, similar data are not available giving joint distributions of these and other characteristics such as size of farm, financial structure of the business, and socioeconomic characteristics of the operator (*10*).

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*The authors are agricultural economists with the National Economics Division, ERS.

[1] Formerly the Statistical Reporting Service.

[2] Italicized numbers in parentheses refer to items in the References at the end of this article.

We are also unable to match data from multiple survey sources to provide an integrated perspective on the economic performance of the farm sector. Surveys are conducted at different times and by different organizations for different purposes. The population to be surveyed also changes. Moreover, if surveys are conducted with different sampling procedures, analytical questions may be raised about the use of multi-source, multi-time-frame data either to develop economic performance measures or to analyze changes in economic structure or behavior.

Over the last decade, and especially over the last 3 years, ERS has been reviewing the conceptual foundations and empirical procedures in the published income, cost of production, balance sheet, and productivity accounts. We have also been reviewing the primary surveys conducted by ERS and NASS to support enterprise costs, productivity, farm income, and balance sheet accounts. Over the last several years, USDA has revised enterprise (cost-of-production) and whole-farm (income) survey questionnaires, sampling methodology, and sample sizes. These revisions will provide a data base sufficient to allow disaggregation of the national accounts to provide statistically reliable data on farms by type, size, and region. USDA has also designed modular questionnaires to easily accept data changes in income, finance, or cost concepts so that future changes in data needs will not cause major changes in survey design.

A Historical Perspective

The quality and use of agricultural data embrace both conceptual development and empirical measurement. The research community, both within and outside USDA, has focused considerable attention for many decades on the quality and potential analytical usefulness of a national agricultural data system for the farm sector to support policy, production, finance, and farm management research.

Conceptual Development

The Committee on Economic Statistics of the American Agricultural Economics Association stated in 1972 that, with continued structural transformations in agriculture and rural life, "theoretical concepts around which we have constructed our data systems grow progressively more obsolete—so obsolete that minor tinkering with each Census or survey no longer seems to bridge the basic inadequacy of the ideas being quantified" (*1*). The Committee left the profession with an ambitious agenda of topics focused on reducing data collection obsolescence. As Lee noted, however, the Committee did not go beyond listing issues that established "the dimensions of social data needs. . ." (*6*). However, several years later, in his presidential address, Bonnen moved the profession well beyond listing data needs by providing insight into conceptual obsolescence in data and by developing a paradigm for an agricultural information system (*3*).

During the sixties and seventies, USDA economists also studied conceptual and empirical data system issues, the latter through statistical redesign of sampling frames for crops and livestock. "The cornerstone for a new farm statistical structure in the United States was laid in 1966 when the Statistical Reporting Service of the USDA put a probability sampling scheme into operation in the 48 contiguous States" (*14*). Beginning in 1970, NASS used list sampling frames to supplement area sampling frames, thus retaining a probability survey design while introducing the "multiframe" sampling procedure into USDA surveys. In 1976, the "multiframe" survey approach was extended to surveys used to collect economic data.

ERS staff has researched the economic concepts and accounting procedures underlying the cost and income accounts published by the Agency. Weeks reviewed aggregate data series published for agriculture and explored alternative approaches to shift the conceptual emphasis in agricultural data toward the same procedures and rationale as the national income and product accounts published by the U.S. Department of Commerce (*17*). A task force on Farm Income and Capital Accounting was established in 1972 and again in 1974 to inventory the basic income and accounting work done in ERS, appraise conceptual content and estimation procedures, and provide recommendations for program improvement (*15, 16*).

Among the 1974 task force conclusions was a recommendation that "net income of farms" be substituted for "net income of farm operations." This recommendation entailed a conceptual shift in the agricultural accounts, meaning that the farm would be measured as a business enterprise or establishment, rather than as a family household or consuming unit.

ERS has also moved toward implementing the conceptual arguments advanced during the previous decade. Revised income accounts first published in 1980 were based on "the concept of separating the measurement of the economic viability of the production units of the farm sector from the well-being of the farm operator families" (*11*). ERS developed a farm production transaction account to measure the income from production establishments so that the value added by the farm production sector can be distributed to the institutions or individuals who control the sector's resources. In this account, the residual is a return to operators. In 1983, ERS also revised cost-of-production accounts by implementing a conceptually stronger methodology and presentation format. The revised cost-of-production budgets measure cash receipts, cash and economic costs of production, and cash-flow measures for enterprises, and they provide a basis for determining the longrun return to farm assets.

Data Problems and the Economic Indicator Accounts

The current data series are increasingly recognized as inadequate for analyzing industry-specific or distributional issues. As Kallek stated in 1981, "There is a growing realization that farms are increasingly different, they have different resource characteristics, needs, and goals. Part-time farms differ from full-time farms as do dairy farms from cash grain farms" (*5*).

We do not discuss all the data voids or inadequacies that exist for the various indicator accounts in this article. These problems must eventually be addressed, however, either through primary surveys or from secondary data sources, such as administrative data provided by other USDA agencies, including the Farmers Home Administration, or other institutions, such as the Farm Credit System. We will highlight a few specific conceptual and empirical data issues to illustrate why ERS is concerned with the appropriateness of its own data collection efforts (*9*).

First, ERS uses production, marketing, and price data obtained from NASS to estimate most components of gross receipts for the farm sector as a whole for most commodities. We are concerned about coverage, however, and we have discussed with NASS ways to improve aggregate estimates of "minor" or specialty crop marketings important to a particular locality, but perhaps less important either to an individual commodity or on a national basis. If these commodities are not properly included in the accounts, gross receipts can be understated.

Second, we include an estimate of the value of home consumption of commodities produced on farms in estimates of net income to help fully account for the use of inputs that are included in sector expenses. Reliable home consumption data exist for livestock, but data for fruits, vegetables, and other crops have not been available for several years. A benchmark has simply been adjusted to reflect changes that could affect consumption. We revised our 1985 surveys to collect consumption value estimates, and we will evaluate these data to determine their usefulness in estimating these accounts.

Third, estimates of the value of the change in inventories are of critical concern. To estimate sector net income from production activities during a specified calendar year, we either add to or subtract from gross income an estimate of the value of the change in physical quantity. We estimate the change in physical quantity stored by subtracting marketings and onfarm use from production. Data have not been collected on the quantity of feed, hay, and other output fed on farms where produced, and benchmark estimates are several years old. Meanwhile, changes in the operating characteristics of the feed-livestock subsector influence estimates of the quantity of grain sold versus the quantity fed, and these changes affect the overall estimates of cash receipts. To address these data problems, USDA added questions to sector surveys conducted for 1984 and 1985. The results from these questions will be used to determine the use of farm-produced feed and to derive a more reliable estimate of inventory adjustments and cash receipts.

Fourth, we have also begun to research and review the gross receipts accounts to determine if additional income sources have been inadvertently omitted. For example, we now charge interest paid on machinery and real estate as an expense, but we do not treat the sale of machinery as capital account transactions or as an income source to the business. Similarly, wages paid to family members are counted as expenses, which is proper for the business, but these wages are not also counted as income when total family income is being measured. Any measure of family well-being is probably understated without consideration of these wages, which amounted to about $3 billion in 1984.

Fifth, we still have not addressed several conceptual and empirical problems. While most expense estimates may have an adequate underlying data base for any particular item at an aggregate level, we do not know how expenses differ for different types of farm businesses. One conceptual issue we are studying is the need to separate livestock purchased for capital account uses from livestock purchased for resale. This separation would prevent overstating production expenses and understating capital expenditures. Survey data from 1984 indicate that about 34 percent of livestock purchases were for breeding stock.

Sixth, interest expense estimates obtained through sector surveys, including the Census of Agriculture, differ significantly from estimates developed from the use of institutional debt and a calculated average interest rate. Survey data, including the 1982 Census of Agriculture, suggest that cash interest expenses may be overstated in the USDA accounts. Moreover, the accounts should distinguish short-term production loans from longer term loans and farm versus household shares. Financial data which more clearly distinquish between operator and landlord debt holdings and debt for farm and nonfarm business purposes (even if the debt were secured by farm collateral, especially real estate) would greatly improve the accuracy and usefulness of both the income and balance sheet accounts.

Seventh, purchased but unused fuel, seed, fertilizer, and feed are expense items that probably should be included in an operating input inventory because many farmers prepurchase and stock these items for later use. To the extent that inputs are purchased but not consumed, income and balance sheet accounts could be incorrectly estimated and net income would be understated during the year of purchase and overstated during the year of use. We collected data to provide an operating input inventory estimate the first time for 1984. Our initial estimate indicated that farmers spent about $1.6 billion on inputs still on hand at the end of the calendar year.

Because we do not know the year of purchase, we will need additional data to track annual changes so that the change in input inventories can be measured and added to or subtracted from gross income and assets measures. We are also collecting data to improve estimates of the costs associated with marketing, hiring, machinery, and custom-work services. These expense items were probably not too significant when the income accounts were being developed many years ago, but they have become far more significant during the past decade.

Finally, we need additional data to improve the cost-of-production (COP) estimates. Specialized farm COP surveys have been used since 1974 to determine application rates, machinery operations, buildings, and other technical information. Because these commodity-specific surveys were taken every 4-5 years, cost estimates are primarily updated between survey years only for changes in input prices. USDA economists derive labor, fuel, lubrication, and repair costs of machinery using engineering equations and relationships derived in the sixties. We should ideally collect data to update all enterprise cost items annually based on a combination of quantity and price changes instead of input price changes only. A more important shortcoming of previous (pre-1984) crop COP surveys is that they were conducted with a nonprobability sampling design. We have consequently not been able to use these data to conduct analyses of enterprise costs concerning the portion of production at certain cost levels, farm size, commodity specialization, and other operating characteristics useful in understanding differences in farm efficiency, costs, and returns. Many of these enterprise cost relationships will be addressed with data collected in subsequent surveys.

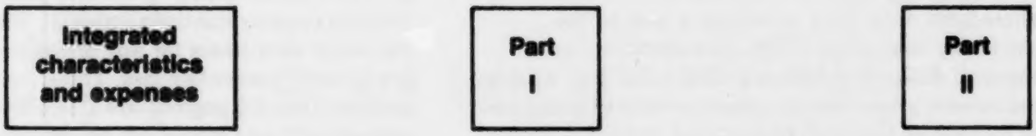
Data Needs and Survey Plans

Prior to 1984, ERS and NASS jointly conducted two independent national surveys: the Farm Production Expenditures Survey (FPES) and the Cost-of-Production Survey (COPS). ERS has spent about $2.2 million on the FPES and COPS, allowing a survey sample sufficient to yield 3,000-4,000 usable COP questionnaires and 7,000-8,000 usable FPES questionnaires annually. The FPES was a probability-based, whole-farm survey collecting total farm expense and receipt data used in preparing national economic indicator series. The COPS collected enterprise-specific technical data by selecting farms proportional to the acreage of selected enterprises. Although similar information was gathered from both surveys, the COPS data could not be used to supplement the FPES, and the FPES could not be used to supplement COPS data (fig. 1). Thus, from the perspective of either survey, much information was irrelevant; from the perspective of distributional analysis, only a portion of the farm business information base needed was available. Because the surveys' data could not be merged, neither survey provided a very reliable source of cross-tabulated data. Even at the national level, some of the data had relatively large measures of dispersion (coefficients of variation for the 1981 FPES ranged from 8.2-15.0 percent, for example).

Maintaining this dual-track enterprise and whole farm survey system caused several other major problems. First, conducting two independent surveys increased overhead costs for survey schools and costs for data collection on those farms in both surveys.

Figure 1

FY 1978-79 Surveys



Farm Production Expenditure Survey

- 16,000 producers
- Whole farm survey
- 30 pages
- Structural and organizational characteristics
- Stratified probability sample by income class of farm
- Each farm has expansion factor
- Aggregate expense statistics calculated
- Conceptual basis for FPES essentially modular with new sections added quickly in response to observed information needs

Cost-of-Production Survey

- 6,000 producers
- Part I: Limited amount of organizational data
  - Cropland ownership and use
  - Farm machinery inventory
- Part II: Enterprise specific technical production practice information
  - Input costs per acre
  - Irrigation practices
  - Machinery operations
- Farms selected on basis of enterprise acreage
- Average per-acre costs aggregated on basis of production patterns
- Nonprobability survey

Second, when the same farm is covered in both surveys, the two surveys competed for producers' time in supplying information; enumerators made multiple visits asking for some of the same data. Third, we were unable to establish data relationships between enterprise activities and the farm business. Finally, we were also unable to answer questions about data reliability, dispersion, and variance of economic indicator measures for different types and sizes of farms by ownership, region, and other characteristics.

Thus, beginning in 1982, ERS and NASS discussed ways to merge the FPES and COPS into a probability-based Farm Costs and Returns Survey (FCRS). This completely integrated whole-farm and commodity-specific survey uses replicated samples for specific detailed (technical or critical problem) information. The FCRS addresses five objectives: (1) estimating COP budget items on a probability basis; (2) redesigning the COPS questionnaires to include whole-farm data, thus providing a link to the previously conducted FPES; (3) enhancing farm financial data; (4) enhancing data collection, editing, and review procedures to reduce overhead costs; and (5) increasing the involvement and technical support for the survey from various data collection and analysis units within ERS and NASS. The newly structured survey is expected to have a sample size of about 24,000 farm operators annually and to have coefficients of variation (CV) less than 4 percent for major expense categories and 10 percent for others.

Because the new FCRS survey is probability-based and has a relatively large sample, we can conduct distributional analyses of operating costs, returns, and financial characteristics by size and type of farm by major producing regions (tables 1 and 2). The CV's for total expenses were dropped to 2 percent in the 1984 survey. Even major components of expenses now carry a CV of about 4 percent or less. More important, the last column of table 1 shows the effect of the survey merger on the quality of the aggregate expense data used to estimate farm income. CV's were substantially reduced; the CV for total expenses dropped from 2.0 percent to 1.7 percent. Another major effect is the ability to develop more statistically reliable cross-tabulations (table 2). Estimated CV's for major data items for any of the farm size classes are about 6 percent or less. Those items with CV's greater than 5-6 percent are items that occur sporadically and would not be expected on a large

Table 1—1984 Farm Costs and Returns Survey: Multiple-frame expansions and coefficients of variation, selected items, expenditure version and all versions

Expense	Multiple-frame expansions		Coefficients of variation	
	Expenditure version	All versions	Expenditure version	All versions
	Million dollars		*Percent*	
Total	129,001	131,514	2.0	1.7
Livestock and poultry	33,272	34,325	3.6	3.4
Farm services	25,411	25,796	2.5	1.9
Feed	18,145	18,341	4.1	3.5
Wages and contract labor	11,125	11,542	3.6	3.3
Fertilizer	8,817	9,144	2.5	2.1
Interest	13,474	13,559	2.5	2.0
Fuels and energy	6,996	6,951	2.3	1.8

Table 2—Farm financial information by acres operated, 1984[1]

Item	Up to 100 acres			101 to 250 acres			251 to 500 acres			500 to 1,000 acres		
	Total	Average per farm	Coefficient of variation	Total	Average per farm	Coefficient of variation	Total	Average per farm	Coefficient of variation	Total	Average per farm	Coefficient of variation
	1,000 dollars	*Dollars*	*Percent*	*1,000 dollars*	*Dollars*	*Percent*	*1,000 dollars*	*Dollars*	*Percent*	*1,000 dollars*	*Dollars*	*Percent*
Gross farm income	14,705,311	22,908	5.30	15,824,779	41,229	4.46	21,891,850	74,096	3.79	27,186,532	137,981	4.40
Livestock and crop marketings	13,565,228	21,132	5.58	14,621,430	38,094	4.63	20,553,396	69,565	3.88	25,264,880	128,228	4.40
All Government farm payments	87,985	137	15.14	215,292	561	10.79	427,451	1,447	7.88	766,071	3,888	6.91
Other farm income	1,052,096	1,639	10.52	988,057	2,574	11.50	911,003	3,083	8.39	1,155,581	5,865	16.11
Operating expense less interest	13,355,793	20,806	5.19	12,597,440	32,821	4.59	17,099,690	57,876	4.04	19,867,383	100,834	4.10
Interest paid on real estate debt	1,119,804	1,744	6.26	893,952	2,329	5.83	1,350,134	4,570	5.90	1,593,421	8,087	5.26
Interest paid on operating loans	373,041	581	8.41	582,772	1,518	6.61	1,057,922	3,581	5.59	1,413,695	7,175	4.74
Net cash income	-143,326	-223	229.03	1,750,615	4,561	14.81	2,384,104	8,069	15.54	4,312,033	21,885	13.98
Off-farm income	12,237,494	19,064	6.07	5,203,618	13,557	6.13	5,281,335	17,875	29.62	1,862,346	9,452	9.54
Farm family income	12,094,167	18,841	6.10	6,954,233	18,118	5.88	7,665,439	25,945	20.28	6,174,380	31,337	10.20
Total farm debt	13,017,852	20,279	5.41	13,947,859	36,339	5.81	22,504,627	76,170	5.12	26,710,272	135,563	4.41
Total farm assets	90,697,745	141,291	4.31	81,456,714	212,224	3.70	96,739,018	327,424	3.56	99,762,757	506,329	4.12
							Percent					
Debt/asset ratio	na	14	4.55	na	17	5.46	na	23	4.14	na	27	3.68
Asset turnover ratio	na	15	5.34	na	18	4.33	na	21	3.20	na	25	3.84
Fixed asset turnover ratio	na	16	5.46	na	20	4.57	na	25	3.44	na	30	4.09
Ratio of interest to total cash expense	na	10	5.18	na	10	4.38	na	12	3.51	na	13	3.28
Ratio of off-farm income to net cash income	na	-8,538	198.47	na	297	15.96	na	222	35.84	na	43	16.91

See footnotes at end of table.

Continued

Table 2—Farm financial information by acres operated, 1984[1]—Continued

Item	1,001 to 2,000 acres			Over 2,000 acres			All acreage classes		
	Total	Average per farm	Coefficient of variation	Total	Average per farm	Coefficient of variation	Total	Average per farm	Coefficient of variation
	1,000 dollars	*Dollars*	*Percent*	*1,000 dollars*	*Dollars*	*Percent*	*1,000 dollars*	*Dollars*	*Percent*
Gross farm income	19,589,235	189,871	5.21	20,800,828	286,769	4.79	119,998,536	70,840	1.86
Livestock and crop marketings	17,987,172	174,343	5.46	18,819,729	259,457	4.99	110,811,835	65,417	1.91
All Government farm payments	907,894	8,800	6.51	953,018	13,139	7.73	3,357,712	1,982	3.39
Other farm income	694,169	6,728	12.44	1,028,082	14,174	8.54	5,828,989	3,441	4.87
Operating expense less interest	15,176,157	147,097	6.23	16,735,312	230,720	4.40	94,831,773	55,983	1.88
Interest paid on real estate debt	1,166,696	11,308	6.82	1,437,319	19,816	6.15	7,561,326	4,464	2.43
Interest paid on operating loans	1,151,771	11,164	5.98	1,398,366	19,279	5.91	5,977,568	3,529	2.44
Net cash income	2,094,610	20,302	20.39	1,229,831	16,955	41.87	11,627,868	6,864	9.14
Off-farm income	1,525,204	14,783	27.02	1,084,065	14,945	9.12	27,194,061	16,054	6.77
Farm family income	3,619,814	35,086	16.71	2,313,896	31,900	22.92	38,821,929	22,918	5.29
Total farm debt	20,368,531	197,425	5.46	23,528,990	324,381	5.31	120,078,131	70,887	2.11
Total farm assets	73,620,078	713,572	5.15	104,411,599	1,439,464	5.18	546,687,910	322,732	1.83
					Percent				
Debt/asset ratio	na	28	4.13	na	23	5.80	na	22	1.95
Asset turnover ratio	na	24	3.97	na	18	5.21	na	20	1.81
Fixed asset turnover ratio	na	29	4.38	na	21	5.63	na	23	1.94
Ratio of interest to total cash expense	na	13	5.12	na	14	4.05	na	12	1.71
Ratio of off-farm income to net cash income	na	73	33.25	na	88	31.56	na	234	11.51

na = not applicable.

[1] Average per farm represents the mean per reporting farm in the sample except for the case of ratios where they are sectoral averages. The coefficient of variation is defined as the standard deviation divided by the mean.

Source: (*8*).

number of farm operations. The probability-based FCRS provides the opportunity to state the accuracy of estimates and to examine and evaluate the sample size. By comparison, in the nonprobability COPS, USDA chose sample sizes using subjective criteria; the sample was drawn from a core of cooperative farmers, and statistical accuracy could not be objectively measured.

The physical and investment characteristics of the farm operation are also included in the FCRS (fig. 2). In part I, for example, enumerators ask each farm respondent for information on general farm characteristics. Farm expenses and income items are recorded in part II and include: whole farm expenses by type or category; land use; crop acreages and yields; livestock inventory, sales, purchases, and feed use; crop receipts, inventory, and so forth; and farm business and financial characteristics. Part III represents the modular sections that are used to obtain specific detailed technical and other farm- or household-related information. This detailed information can then be related to general farm characteristics because of the subsampling procedures which are based on preselection with known probabilities. Such detailed data collection procedures provide primary survey data on particular types or categories of farm business and farm households, their organizational characteristics, and their operating or technical practices.

Several repercussions will occur with the new survey approach. We will have more rigid, formal, and complex procedures both when conducting the survey and when using the data. We will also be able to evaluate and report on the accuracy of the data so that data users can evaluate their reliability for other analytical purposes.

Distributional Indicator Data Series: Enhancing the Aggregate Perspective

The ability to focus analyses on certain types and kinds of operations was perhaps unimportant when the farm sector was composed of several million farms, mostly small and reliant on agriculture for family income. Relative homogeneity within the sector meant aggregate measures could be used to discuss economic well-being of the component subsectors. However, agriculture has become increasingly and noticeably heterogeneous. As a result, aggregate economic accounts and data series, constructed in the absence of distributional considerations, have become increasingly ineffective in providing insight into the well-being of various farm subpopulations. Sundquist illustrated this point in 1970 by arguing that "...there seems to be little merit in speaking of average income, average problems, or average anything for...units...classified as farms" (*12*).

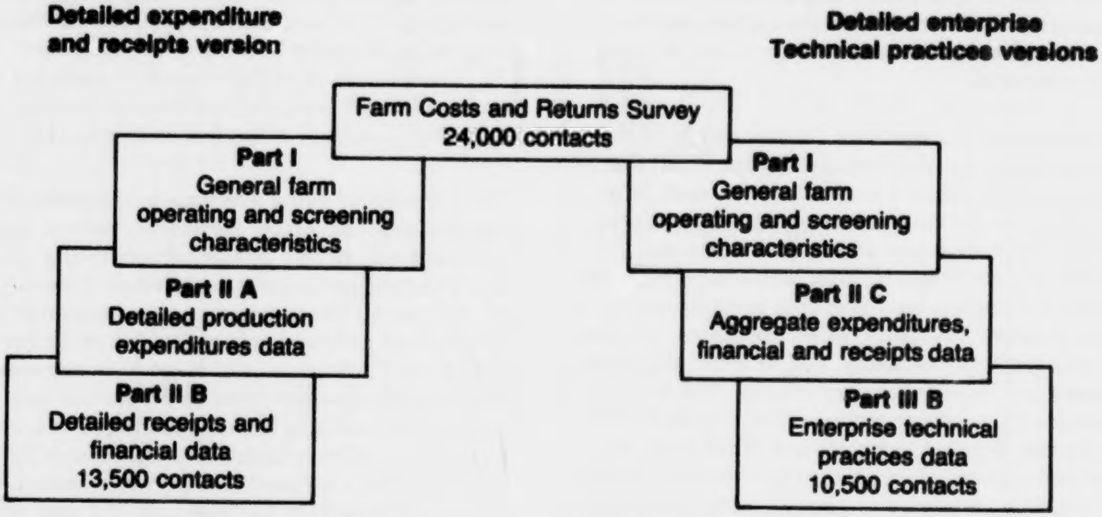
The difficulty of using averages to represent commercial and noncommercial operations, various legal organizations, tenure groups, or commodity subsectors becomes particularly acute when the analyses are focused on the distributional consequences of agricultural and economic policy and on financial conditions (*7*). Johnson and Short have suggested that "using aggregate sales or production data to assess distribution of information requires a strong assumption, often untenable, about class composition" (*4*). This viewpoint will probably become increasingly important for future agricultural policy and research efforts.

USDA designed the 1984 FCRS to provide financial characteristics of the farm business, sales, operator occupation and off-farm income, production, capital expenditure, and Government-program participation in addition to the usual expense data. For example, the data in table 2 were derived from the 1984 FCRS and demonstrate conclusively that producers in the differing acreage classes varied substantially with regard to every operating characteristic shown. Even a superficial analysis of these data strongly suggests that conclusions reached using just aggregate data for policy or program purposes would probably be misleading or incorrect.

This point is made even more emphatically by the data on the sources and uses of cash income of farms producing corn (table 3). Corn farmers' level and sources of gross cash income vary considerably by region. Expenses, especially interest paid, also vary considerably by region. Farmers growing corn show net operating margins ranging from a large positive to a large negative. Moreover, the level of farm business leverage and off-farm income varies considerably. This variation illustrates the difficulty in using aggregate sector data to estimate either the

Figure 2

The Farm Costs and Returns Survey: FY 1985


Detailed expenditure and receipts version
Detailed enterprise Technical practices versions
Farm Costs and Returns Survey 24,000 contacts
Part I General farm operating and screening characteristics
Part II A Detailed production expenditures data
Part II B Detailed receipts and financial data 13,500 contacts
Part I General farm operating and screening characteristics
Part II C Aggregate expenditures, financial and receipts data
Part III B Enterprise technical practices data 10,500 contacts

Part I: Screening and general farm operating characteristics:

- Land use
- Crop acreages, yields, and so forth
- Farm business and financial organization

Part II: Farm production expenditures, receipts, and financial data, including items such as:

- Whole-farm expenses by type or category
- Livestock inventory, sales, and purchases
- Crop receipts, inventory, and so forth
- The farm business balance sheet

Part III: Modular sections for specific detail

A. Detailed information needs for special and key variables and data items relating to production activities and whole farm expenses

B. Data on particular types or categories of farm organizational characteristics and technical practices used in crop and livestock production

Table 3—Sources and uses of cash income on farms producing corn, by region, 1984[1]

Item	Northeast	Lake States	Corn Belt	Northern Plains	Appalachia	Southeast	Delta	Southern Plains	Mountain States	Pacific States	All regions
	Number										
Sample size	610	997	1,450	427	748	258	92	81	342	174	5,179
Expanded number of farms	59,104	140,733	227,522	62,159	81,569	29,017	6,716	8,171	10,051	4,354	629,396
Expanded share of all farms (percent)	9	22	36	10	13	5	1	1	2	1	100
	Dollars per farm										
Livestock sales	74,977	54,029	43,756	65,459	37,857	26,545	32,776	66,536	129,774	302,493	52,912
+ Crop sales	16,065	25,127	49,093	54,979	32,009	53,637	31,550	83,440	60,211	257,412	41,087
= Cash sales	91,042	79,156	92,850	120,438	69,866	80,182	64,326	149,976	189,985	559,906	93,999
+ Government payments	985	2,290	1,739	4,667	806	1,386	2,233	4,683	3,361	8,053	2,056
+ Other cash income	1,923	2,566	2,746	6,885	2,269	1,665	788	5,907	9,598	19,961	3,174
= Gross cash income	93,949	84,012	97,335	131,990	72,940	83,232	67,348	160,566	202,944	587,920	99,230
− Interest paid	6,852	11,676	11,696	16,454	6,180	7,913	8,262	18,638	26,851	61,060	11,454
− Other operating expenses	72,775	62,624	67,947	99,099	53,884	77,089	61,760	162,850	186,566	478,423	74,785
= Net operating margin	14,323	9,712	17,692	16,436	12,876	-1,770	-2,674	-20,922	-10,472	48,437	12,990
+ Off-farm income	7,773	11,943	12,452	4,563	12,721	11,248	11,045	13,370	4,170	10,237	10,949
= Total cash available	22,095	21,655	30,144	21,000	25,597	9,478	8,372	-7,551	-6,303	58,674	23,939
− Family Living expenses	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950	12,950
− Principal payments	5,718	9,431	9,226	11,404	4,385	5,825	7,153	15,264	18,185	45,494	8,823
= Cash balance	3,427	-726	7,969	-3,355	8,262	-9,297	-11,731	-35,765	-37,437	230	2,165
Total value of owned assets	345,531	352,885	364,383	457,304	274,629	314,489	302,005	548,960	911,793	1,384,211	372,813
Total value of debt	66,492	109,663	107,275	132,606	50,988	67,734	83,174	177,488	211,452	528,998	102,598
	Percent										
Debt/asset ratio	19.24	31.08	29.44	29.00	18.57	21.54	27.54	32.33	23.19	38.22	27.52
Debt as a share of U.S. debt	6.09	23.90	37.80	12.77	6.44	3.04	0.87	2.25	3.29	3.57	100.00
Assets as a share of U.S. assets	8.70	21.17	35.33	12.11	9.55	3.89	0.86	1.91	3.91	2.57	100.00
Balance as a share of cash sales	3.76	na	8.58	na	11.83	na	na	na	na	.04	2.30
Balance as a share of total assets	.99	na	2.19	na	3.01	na	na	na	na	.02	.58
Share of farms with negative or zero cash balance	58.01	48.50	47.04	55.51	45.60	57.63	77.92	70.78	58.86	45.79	50.35
Share of farms participating in Government programs	16.53	37.03	37.17	55.82	23.21	19.22	18.30	15.65	29.44	31.74	33.77

na = not applicable, because cash balance is negative.

[1] Data may not add because of rounding.

solvency, liquidity, or profitability of a business or the probable effects of policy adjustments on a particular segment of the industry.

Other cross-classifications can be developed from the FCRS to enhance financial analyses of the farm business establishments. Because these data are based on a multiframe probability sample of nearly 24,000 farms, reliable national and regional estimates are easily obtained. Other distributionally related microeconomic indicators can be organized by size (such as acreage or sales class), occupation, tenure, or farm business organization. Of course, when the data are disaggregated to provide a disaggregated perspective, thin data in a specific individual cell are possible. When this situation occurs, thin data estimates should be used only as a guide to the characteristics of farms in the subpopulation rather than as a precise estimate.

To reduce the incidence of thin data cells, USDA has recommended an increase in funding. This funding would also allow USDA to expand the FCRS sample size so that reliable aggregate data can be obtained at the State level. These aggregate data would allow multiple-dimension cross-tabulations at the national and regional levels. Moreover, the expanded survey would provide sample data that can be used to develop more disaggregated national perspectives of changing conditions in the farm sector by type, size, and other characteristics.

Conclusions

Aggregate agricultural statistics and indicators have long served as measures of economic well-being of the farm sector. In the future, economic indicators will need to be disaggregated to be useful for policy and program analysis. To meet this demand for different farm-sector data and for information better describing changing economic conditions, USDA merged the previously conducted FPES and COPS into a new and broader economic survey, the FCRS.

The FCRS is an integrated, probability-based, annual national whole farm survey conducted to improve both aggregate and disaggregate economic indicators needed by Government officials as well as by farmers and others who make decisions that affect the farm sector. The resulting data set includes detailed information on financial characteristics, expenses, receipts, resource base, and production practices on farms. To be even more useful, the FCRS will also provide other socioeconomic data such as age, education, and off-farm income. These data will allow not only more accurate estimates of farm-sector income but also a better grasp of income distribution among sector participants, while contributing to our goals of maintaining conceptual clarity, flexibility, and progressive adaptability for the future.

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Over the years, the price of human time has risen greatly relative to that of the services of natural resources. Real hourly wages in the United States were more than five times as high in 1972 as they were in 1900, whereas the real price of the commodities most dependent on natural resources tended not to rise.

Theodore W. Schultz
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Money and Agriculture: The Dynamics of Money-Financial Market-Agricultural Trade Linkages

By David Orden*

Abstract

This article investigates empirical relationships among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices using three- and six-variable vector autoregressive models. Shocks to the money supply have little direct effect on agriculture, whereas positive interest rate, exchange rate, and general-price-level shocks have negative effects. The dynamic patterns characterizing monetary interactions with the financial variables do not preclude the possibility that monetary policies underlie the observed interest rate and exchange rate impacts, but the observed price-level shocks appear to be independent of the money supply. Agricultural exports and prices demonstrate little impact on the macroeconomic variables.

Keywords

Macroeconomic-agricultural linkages, exchange rate effects on agriculture, inflation and agriculture

Introduction

This article investigates macroeconomic impacts on agriculture. The analysis focuses on relationships among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices. These relationships are central to recent discussions of macroeconomic-agricultural linkages, but they remain imperfectly understood. To help clarify the interactions among these variables, I use three- and six-variable vector autoregressive (VAR) models in which quarterly data are viewed as generated by own- and cross-variable dynamic responses.

Several issues arise at the outset. First, assessing macroeconomic impacts on agriculture is elusive despite the importance of these impacts to both private decisionmakers and agricultural policymakers. This ambiguity is due in part to the diversity of plausible conceptual approaches that have been suggested about macroeconomics and linkages from macroeconomics to agriculture. Thus, one of my objectives is to review some of these approaches.

A second set of issues concerns the use of VAR models in economic analysis. Given the diversity of theories suggested to characterize macroeconomic-agricultural linkages and the empirical evidence marshaled to support each of them, it seems appropriate to examine the historical evidence to see which views are consistent with past experience before imposing a particular model. VAR models offer one useful approach to such an analysis. VAR models can help us clarify theoretical and empirical controversies over these linkages and can help us evaluate the potential effects of alternative policies. VAR models also provide a basis for assessing the importance of alternative sources of instability in the agricultural sector, and they can help us with economic forecasting.

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Considerable mystery has surrounded the recent use of VAR models for these purposes, and their use remains controversial. The mystery arises primarily from a general lack of familiarity among applied economists with the analytic techniques, diagnostics, and standard methods of reporting associated with VAR models. The controversy arises over whether appropriate characterizations of economic dynamics are provided by these models and whether policy interpretations can be associated with their outcomes.

Because of the importance of these issues, I also describe some of the mechanics of VAR modeling and the basic controversies concerning their interpretation. My objective is to help readers unfamiliar with VAR models place the empirical results in an appropriate perspective, not to break new ground in methodology.[1]

Following the sections on methodology, I specify a six-variable empirical model of macroeconomic-agricultural linkages. I compare dynamic interactions in the six-variable model with those in a simpler model restricted to the money supply, agricultural exports, and agricultural prices. Although the agricultural variables seem largely independent of money in the restricted model, shocks to the financial market variables and the general price level have substantial impacts on agriculture. Alternative theoretical perspectives are evaluated in light of this evidence.

Theoretical Perspectives

The agricultural sector has long had an interest in relationships between agriculture and the rest of the economy. With the rapid expansion of trade during the seventies, this attention centered on the impact of the exchange rate on agricultural exports and prices. Early analytic and empirical studies focused on the effects of a currency realignment, taken as exogenous, on the domestic and foreign prices of a specific commodity and on the equilibrium quantity traded (*6, 15*). Later, it was recognized that potential cross-price effects arise from the simultaneous impact of an exchange rate realignment on the prices of many commodities (*5, 18*). The additional effects of income shifts associated with changes in the real exchange rate have recently been recognized (*20*).

Because exchange rates are a crucial transmission mechanism by which macroeconomic factors bear on agricultural trade, and thus on U.S. agriculture overall, it is not surprising that many recent empirical studies have focused directly on measuring these impacts. Refining our estimates of key parameters and furthering our knowledge of conceptual issues related to these impacts are important in quantifying these effects. Furthermore, when the exchange rate moves markedly, as it has over the past few years, the consequences for agriculture are of concern to the sector regardless of the underlying causes of the exchange rate realignment. That is, the exchange rate itself is the macroeconomic variable of interest for some purposes.

However, policy analysis cannot progress far without an understanding of the factors that underlie movement of variables such as the exchange rate. Isolating policy-induced movements in these variables is crucial. Following the pioneering work by Schuh (*22*), this effort has focused on the impacts of monetary and fiscal policies. With flexible exchange rates and well-integrated international capital markets, Schuh argues, tight monetary policy and/or expansionary fiscal policy induces a capital inflow and an appreciation of the currency (*23*). Agriculture and other trade sectors bear the brunt of policy adjustment as exports decline and imports rise.[2]

By focusing attention on monetary and fiscal policies, Schuh and others generalize the issue of macroeconomic impacts on agriculture in two important respects. First, macroeconomic policies may affect agriculture through many mechanisms other than the exchange rate. Potential policy effects through interest rates, national incomes, international liquidity, and other facets of the economy need to be taken into account. Second, and perhaps more important, the evaluation of macroeconomic impacts on agriculture confronts the contemporary issue in macroeconomic theory of whether, and if so, when, macroeconomic policies have real impacts. Establishing a link from macroeconomic policy to agriculture requires establishing avenues by which macroeconomic policies affect the economy. Alternative models suggest quite different perspectives on this issue.

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[1] In presenting a case for the utility of VAR analysis, I will leave it to others to present alternative views. This omission is by no means intended to deny the importance of the controversy. Interested readers should see (*3, 7, 12*). Italicized numbers in parentheses refer to items in the References at the end of this article.

[2] Though Schuh has been instrumental in calling attention to the potential effects of monetary and fiscal policies on agriculture, his articles (*24, 25*) place the impact of these policies in a broad context.

Two viewpoints illustrate some of the basic macroeconomic controversies. In the first, the economy is viewed in terms of a stochastic equilibrium model in which all prices are flexible, agents have rational expectations, and markets clear. In such a model, anticipated changes in the money supply have known effects on nominal income and proportionate effects on individual prices and the general price level. Hence, real economic activity is not affected. An unanticipated monetary shock, in contrast, is partly confused with shifts in relative demand, and it induces output responses. If price elasticities of supply and demand differ across markets, a monetary shock may affect relative prices and have different impacts among sectors. Thus, in a stochastic equilibrium model, changes in the money supply can have real impacts, but policymakers may be unable to exploit these effects systematically to influence developments in the economy.

An alternative to the market-clearing equilibrium model is an approach in which some prices are less than perfectly flexible for some medium-length period.[3] Commodities fall into one of two categories: fixed-price or flex-price. Two crucial characteristics then distinguish the fixed-price/flex-price model from the stochastic equilibrium model. First, even anticipated monetary policy may have real effects because of the inability of some prices to adjust in the short run. Second, macroeconomic policies may cause excessive price movements (price overshooting) in flex-price markets where the burden of policy impact is initially absorbed. A key result is that expansionary monetary policy, though inflationary, may benefit agriculture as flexible agricultural prices rise faster than the overall price level. Rausser has characterized this overshooting in response to expansionary monetary policy as a subsidy to the agricultural sector (*21*).

The study of market structure has produced a third view of the effects of inflation on agriculture. The market structure approach, like the fixed-price/flex-price macroeconomic model, is characterized by a dichotomy between flexible agricultural prices and administered (that is, fixed) industrial prices. In this view, increases in input and other industrial prices arising in oligopolistic or price-setting industries are not necessarily passed on to agricultural output prices, which are determined in competitive markets (*29*). Rising industrial prices place agriculture in a cost-price squeeze, so farmers experience a decline in relative prices during inflationary periods. This is just the opposite of what happens in the fixed price/flex-price macroeconomic model.

One can understand the discrepancy between these latter two views of the effects of inflation on agriculture in terms of alternative assumptions about the causes of price changes and the behavior of the monetary authorities. In the fixed-price/flex-price model, monetary expansion causes inflation and the associated upward overshooting of agricultural prices. In the market structure approach, an increase in administered industrial prices causes relative agricultural prices to fall. This exogenous price shock is associated implicitly with inflation, but the linkage of rising administered prices to the money supply and monetary policy is not precise. Such an autonomous price shock arising in the fixed-price sector could also generate both inflation and a decline in flexible prices relative to fixed prices in a fixed-price/flex-price macroeconomic model.

Opposed to each of the preceding analyses—which, despite their differences, center on responses of the agricultural sector to developments arising outside the sector—is a fourth line of reasoning concerning macroeconomic-agricultural linkages. It focuses on agriculture as a source of instability within the overall economy. This concern was particularly acute in the early seventies when food and oil prices were explosive (*2, 11, 30*). From this perspective, explaining relative agricultural price movements as a function of general price movements may have cause and effect exactly reversed. Models in which exogenous macroeconomic developments are assumed to affect agriculture, with impacts from agriculture on the macroeconomy precluded, are called into question.

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[3] See (*5*) for a further discussion of stochastic equilibrium models and (*21*) for a review of the literature on fixed-price/flex-price models.

Vector Autoregressive Models

Vector autoregressive econometric analysis begins with selecting a set of variables perceived as relevant to an economic issue under investigation. These variables may be transformed to remove nonlinearity, trend, or seasonal components. The modeling begins with estimation of a set of regression equations in which the current value of each variable is expressed as a function of lagged values of the selected variables. No variable is assumed to be exogenous *a priori*, and no variable is excluded from the autoregressive equation for any other variable. Because each autoregressive equation has the same right-hand-side regressors, ordinary least squares (OLS) provides an efficient estimation procedure.

Regression analysis is quite familiar and, were analysis of VAR models to proceed on the basis of the estimated autoregressive equations, it too would be familiar. However, when there are no exogenous variables, the regression equations do not have a natural interpretation. The autoregressive parameters explain how each variable evolves through time, given past values of the variables in the model. But the usual types of analysis, such as determining the effect of an exogenous change in an independent variable on the dependent variable, are unnatural when all right-hand-side variables themselves evolve in a way specified by the estimated equations.

A more natural approach to a VAR model is to distinguish between the expected evolution of the economy (represented by the autoregressive parameters) and the deviations from this evolution occurring over time as a result of unexpected shocks. These shocks are measured by the error terms of the autoregressive equations. One can evaluate interactions among variables in a VAR model by examining the effects of these errors on the subsequent evolution of all variables in the model.

To accomplish this task, one transforms the estimated autoregressive equations to derive a moving-average representation of the VAR. This transformation may be viewed as the outcome of a sequence of substitutions in which lagged values of right-hand-side variables are replaced by their own autoregressive equation. Each substitution backdates the values of actual variables that appear in the initial equation by one period and introduces errors from an additional lag.

To illustrate, consider the transformation of a two-variable, one-lag autoregressive model:

$$\begin{aligned} x_t &= d_{11}x_{t-1} + d_{12}y_{t-1} + e_t \\ y_t &= d_{21}x_{t-1} + d_{22}y_{t-1} + h_t \end{aligned} \tag{1}$$

where the expected values of e_t and h_t are zero and the errors are not serially correlated. If one considers just the x variable, the first step of the transformation to the moving-average representation is:

$$\begin{aligned} x_t = {} & d_{11}(d_{11}x_{t-2} + d_{12}y_{t-2} + e_{t-1}) \\ & + d_{12}(d_{21}x_{t-2} + d_{22}y_{t-2} + h_{t-1}) + e_t \end{aligned} \tag{2}$$

Continuing this process, one derives:

$$\begin{aligned} x_t &= e_t + a_{11}e_{t-1} + \ldots + \qquad a_{21}h_{t-1} + a_{22}h_{t-2} + \ldots \\ y_t &= \qquad b_{11}e_{t-1} + \ldots + h_t + b_{21}h_{t-1} + b_{22}h_{t-2} + \ldots \end{aligned} \tag{3}$$

where the a_{ij}'s and b_{ij}'s are nonlinear combinations of the autoregressive parameters (d_{ij}'s).[4]

An advantage of the moving-average representation compared with the autoregressive equations is that the coefficients of the moving-average representation describe exactly how a shock to a particular variable at one moment in time shifts the expected time path of each variable in the model compared with its expected evolution had the shock not occurred. For example, in equations (1) - (3), the effect of a one-unit shock to variable y at time t-1 on x_t is a_{21} and on y_t is b_{21}, while the effect of a shock to y at time t-2 on

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[4] The autoregressive and moving-average representations can be expressed compactly in matrix notation. See (*13*) for a good discussion of the methodology.

x_t is a_{22} and on y_t is b_{22}. Likewise, the effect of a shock to y at time t on the expected value of some future x, say x_{t+i}, is given by a_{2i}, and so on. Thus, the coefficients of the moving-average representation provide impulse response functions that trace either how current values of each variable are affected by shocks in the past or how expected future values of each variable are affected by a shock today. These impacts are intractable in the autoregressive parameters because a specific shock has both direct and indirect effects on the evolution of each variable. Notice too that the effects of a specific shock are computed assuming no additional shocks occur. Hence, the impulse response functions describe changes induced by an initial shock assuming all variables then evolve naturally, rather than holding all else constant in the usual sense.

The moving-average representation also provides a second useful measure of the impacts of the variables in the model on one another. Future values of each variable are forecast assuming all future shocks have their expected value of zero. Because these shocks are random, the variance of these forecasts can be computed. The variance for each forecast can then be apportioned or decomposed into components due to each variable. This decomposition is based on the variance of the shocks to each variable (estimated from the error terms of the autoregressive equations) and the impacts of these shocks on each forecast (estimated by the coefficients of the moving-average representation). Such a decomposition provides a preliminary assessment of dynamic interactions among the variables.

One complication that often arises is that the errors associated with specific variables (for example, e_t and h_t in equations (1) - (3)) are contemporaneously correlated. Cross-product terms in the forecast variance expressions then make it impossible to decompose forecast error variances. The usual procedure in this case is to choose a particular ordering of the variables in the model and to remove from the shock to each variable that portion which is explained by contemporaneous shocks to variables earlier in the chosen order. This procedure of orthogonal ordering is equivalent to including the current value of variables earlier in the order on the right-hand-side of autoregressive equations for variables that follow. This procedure imposes a recursive causality on the variables selected for analysis. A particular order must be chosen as part of the specification of the model, and altering the order may affect estimates of the dynamic relationships among the variables. Hence, examining models with alternative orthogonal orders provides a guide to interpreting reported outcomes and is a useful test of the robustness of specific results.

Interpretation of VAR Models

The preceding discussion clarifies some of the mechanics of VAR models. Their interpretation in economic analysis and their use in policy evaluation raise a related, but somewhat different, set of issues. Because there are no exogenous variables in a VAR model, each variable potentially affects all other variables. This generality is appealing in cases where several plausible theories have been suggested concerning the economic dynamics, but it precludes usual identification of a structural model.[5]

The moving-average representation of a VAR model focuses the analysis on the error terms associated with the autoregressive equations; own- and cross-variable dynamic impacts of these shocks are evaluated. Interpreting a VAR model depends on connecting each of these shocks to a specific variable in the economy. Usually such a connection is made between the equations of a structural model and specific variables. The autoregressive equations from a VAR model are equivalent to the reduced-form equations from such a structural model. But when a reduced form is derived from a structural model, the reduced-form errors are generally linear combinations of the errors from the structural equations. Thus, no direct association is made between these errors and specific aspects of the economy.

Under special circumstances, dynamic effects of shocks associated with VAR equations will exactly match those of shocks to equations of a structural model. This situation occurs when the structural model is diagonal (only lagged values of other variables enter the structural equation for each variable) or when the structural model is recursive and the orthogonal ordering of the VAR model exactly matches this recursive order.

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[5] Formal arguments favoring this approach to econometric modeling have been presented by Sims (27). He suggests that a structure based on *a priori* exogeneity and exclusion restrictions is rarely justified. His argument is based on the relatively small number of distinctions that imply appealing restrictions, the difference between exogenous and lagged endogenous variables with respect to structural identification when lag length and serial correlation are not known, and the effects of expectations on the behavior of economic agents, which tend to undermine potential exclusion restrictions.

The true model of the aspects of the economy under investigation is, of course, rarely known and will not necessarily satisfy the diagonal or recursive criterion. Impulse response functions from a VAR model may then misrepresent the dynamics of shocks to the true structural equations. Likewise, estimates of the dynamic effects of shocks to a misspecified structural model will also misrepresent the true dynamics.[6] The fundamental controversy over using VAR models in economic analysis is based on this dilemma. Using a VAR model rests on the conviction that important dynamics in the economy are usefully captured by its moving-average representation.

A Model of Money, Financial Markets, and Agriculture

To provide some empirical insights into the relationships among money, financial market variables, inflation, and agriculture, I specified a six-variable VAR model. Variables in the model were: (1) the seasonally adjusted U.S. money supply (M1), (2) the interest rate on 3-month Treasury bills, (3) a trade-weighted index of the value of the dollar ($*/$) against the currencies of 10 industrial countries, (4) the general price level as measured by the U.S. gross national product (GNP) deflator, (5) the value of U.S. agricultural exports, and (6) agricultural prices as measured by the index of prices received by farmers for all crops. I estimated the autoregressive parameters of the model using quarterly data from 1960(1) through 1984(3) without allowing for parameter variation during the estimation period. Four lags of each variable were included in the autoregressive equations; each autoregressive equation also included constant, trend, and seasonal terms. I evaluated all variables, except the interest rate, in natural logarithms. To account for contemporaneous correlations among the errors, I orthogonalized the model initially in the order in which these six variables appear. This order allows the greatest opportunity for macroeconomic factors to affect agriculture, and not vice versa. This order also allows the greatest possible influence for the money supply variable.

I estimated the parameters of the model reported here using nominal values of the interest rate, the exchange rate, the value of agricultural exports, and the index of crop prices. An alternative approach is to deflate these nominal values prior to estimation. Using a deflated model is appealing for this analysis because real changes can be expected to be important among sectors of the economy. However, constructing deflated values prior to estimation moves the analysis away from variables that are directly observable. One result is to entangle the dynamics of price-level effects with the effects of other variables.[7] Furthermore, one can generally derive the real effects of specific shocks from the model estimated in nominal terms by subtracting the simultaneous effects of various shocks on the price level from their effects on other nominal variables.[8] The results from a nominal model are also more directly comparable with those from macroeconomic VAR models in which construction of deflated variables has generally been avoided.

Table 1 shows the R-squares and standard deviations of errors associated with the autoregressive equations from the six-variable, macroeconomic-agricultural model. Table 2 reports the results of F-tests for the null hypotheses; coefficients on lags associated with particular variables are zero in each of the autoregressive equations. Table 2 shows the probability of the corresponding (but not reported) F-statistic occurring if the null hypothesis were true.

The F-tests in table 2 have several implications. First, they show substantial evidence of macroeconomic impacts on agriculture. Lagged exchange rates are significant in the equation for agricultural exports, and lags of all four macroeconomic variables are significant in the equation for agricultural prices. There is also evidence of complex interactions

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[6] See (*1*) and (*14*) for a further discussion.

[7] In a related paper (*19*), I presented the results from a model estimated using an *ex post* real interest rate, a real trade-weighted exchange rate, and deflated values of agricultural exports and prices. Interested readers may want to compare the two sets of outcomes. The key conclusions from the analysis are supported by comparable results from the two approaches to estimation.

[8] The derivation is not possible for the exchange rate unless the nominal model includes an index of foreign price levels.

Table 1—Measure of fit and standard deviation of the errors, autoregressive equations, six-variable macroeconomic-agricultural model

Variable	R-square	Standard deviation of errors
Money supply (M1)	0.9998	0.00465
Interest rate	.9568	.63926
Exchange rate	.9732	.01914
Price level	.9999	.00268
Agricultural exports	.9907	.07698
Agricultural prices	.9908	.03719

among the macroeconomic variables. Lagged values of both the money supply and the interest rate are significant in the money supply and interest rate equations, and lags of three of the four macroeconomic variables are significant in the exchange rate equation. In contrast, only own lags are significant in the price-level equation. Effects of the agricultural variables are not significant in the equations for the macroeconomic variables.

Table 3 shows the decomposition of variance for forecasts 4 and 12 quarters ahead for the six-variable model. Table 3 also shows the decomposition of forecast variance for a three-variable model that includes only the money supply, the value of agricultural exports, and the index of crop prices. This comparison is particularly relevant in light of past observations that the explanatory power of money supply shocks in a three-variable macroeconomic model (money supply, real output, and the price level) is reduced substantially in expanded models that also include financial variables such as the interest rate.[9] One might also compare the results from the restricted model with other recent studies of macroeconomic-agricultural linkages in which the money supply is the only macroeconomic variable included in the analysis (*4*, *10*).

Table 2—Significance of the lags of each variable, autoregressive equations, six-variable macroeconomic-agricultural model

Dependent variable	Lagged variables					
	Money supply	Interest rate	Exchange rate	Price level	Agricultural exports	Agricultural prices
	Significance level of the F-statistic					
Money supply (M1)	*	*	0.306	0.890	0.767	0.480
Interest rate	**0.024**	*	.484	.103	.725	.862
Exchange rate	.112	*	*	**.037**	.784	.144
Price level	.151	0.396	.743	*	.775	.244
Agricultural exports	.558	.767	*	.081	.255	*
Agricultural prices	*	**.006**	*	**.004**	.137	*

Boldface indicates cases for which there is evidence for rejecting the null hypothesis at the 95-percent confidence level.
* indicates a significance level of less than 0.001.

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[9] Sims reports that the money supply variable appears largely exogenous in a three-variable VAR model with real gross national product (GNP) and the price level (that is, own shocks explain 81 percent of its forecast error variance at 14 quarters ahead) and that money shocks explain a large fraction of the variance in forecasts of real output in this model (*28*). A positive monetary shock induces a temporary rise in output and a slower, steady rise in the price level. These results are consistent with shortrun real effects of monetary shocks in a stochastic equilibrium model and with the hypothesis that instability in monetary policy has been a prime cause of price and output movements in the economy. In autoregressive models that include financial variables, however, the role of money shocks is substantially reduced (*26*, *28*). Much of the explanatory power of money in the three-variable model is transferred to the interest rate.

Table 3—Decomposition of 4- and 12-quarters-ahead forecast error variances, three-variable and six-variable macroeconomic-agricultural models

Variable	Quarters ahead	Shocks to—					
		Money supply	Interest rate	Exchange rate	Price level	Agricultural exports	Agricultural prices
	Number	*Percent of forecast error variance*					
Money supply	4	60.3	36.1	0.2	1.4	1.5	0.5
	12	44.1	36.0	1.5	9.6	1.5	7.3
	4	(98.4)				(2.3)	(4.3)
	12	(65.6)				(6.1)	(28.3)
Interest rate	4	39.4	55.7	.7	2.4	1.3	.5
	12	23.8	28.4	22.6	8.2	1.1	15.9
Exchange rate	4	3.7	30.8	58.4	3.7	1.1	2.3
	12	15.8	34.6	42.2	3.8	.6	3.0
Price level	4	14.3	1.7	3.6	78.1	1.3	1.0
	12	10.5	23.9	34.1	25.6	1.4	4.5
Agricultural exports	4	3.0	4.8	12.2	9.7	55.6	14.7
	12	12.0	36.9	22.7	5.4	17.3	5.7
	4	(2.5)				(86.9)	(10.6)
	12	(2.1)				(87.7)	(10.2)
Agricultural prices	4	1.8	13.3	2.3	8.5	16.0	58.1
	12	8.5	38.2	9.8	16.2	5.5	21.8
	4	(9.8)				(37.5)	(52.7)
	12	(8.8)				(56.7)	(34.5)

Numbers in parentheses indicate decomposition of forecast error variances for a three-variable model.
Blanks indicate not applicable.

In the three-variable macroeconomic-agricultural model, own shocks explain almost all the variance in 4-quarter-ahead forecasts of the money supply; a substantial fraction of this variance in a 12-quarter forecast horizon is explained by shocks to agricultural prices. Shocks to agricultural exports have little effect on the forecast error variance for money.

Despite the relatively large proportion of own forecast error variance explained by shocks to the money supply in the three-variable model, money shocks have only slight effects on the forecast error variance of the agricultural exports and price variables. Indeed, agricultural exports appear largely exogenous, whereas shocks to exports have a substantial impact on the variance of agricultural price forecasts. These results seem to suggest the importance to agriculture of sectoral, rather than macroeconomic, factors.

When the interest rate, the exchange rate, and the price level are added to the three-variable model, the effects of money shocks on agricultural exports and relative prices remain relatively small. Three important new results emerge, however.

First, the proportion of own forecast error variance explained by money shocks declines, and money shocks affect the forecast error variance for the interest rate and the exchange rate. These results are consistent with outcomes from macroeconomic models that include financial variables (*9, 28*). The interest rate and the exchange rate have a strong interaction in the macroeconomic-agricultural model. Their shocks jointly explain over 50 percent of the variance in interest rate forecasts 12 quarters ahead and over 70 percent of the variance in exchange rate forecasts 12 quarters ahead.

Second, the fraction of forecast error variance of the agricultural variables explained by sectoral shocks falls substantially. Own shocks explain only 17.3 percent of the 12-quarter-ahead forecast error variance of agricultural exports in the six-variable model, compared with 87.7 percent in the three-variable model. Likewise, agricultural export and price shocks explain only 5.5 percent and 21.8 percent, respectively, of the variance of 12-quarter-ahead agricultural price forecasts (compared with 56.7 and 34.5 percent, respectively, in the three-variable model). Most of the lost explanatory power is absorbed by the interest rate and the exchange rate, in the case of agricultural exports, and by the interest rate and the price level, in the case of agricultural prices.

Third, the decomposition of forecast error variance for the six-variable model suggests very limited effects of the two agricultural variables on the forecast error variances of the macroeconomic variables. The proportion of M1 forecast error variance attributable to agricultural price shocks is reduced compared with the three-variable model, and the agricultural variables explain little of the forecast error variance for the additional macroeconomic variables. These results are invariant to placement of the agricultural variables ahead of the macroeconomic variables in the orthogonal order.

Some further insight into the economic dynamics is provided by the impulse response functions for the three- and six-variable models. In the three-variable model (not shown), a money supply shock declines slowly over eight quarters. A shock to agricultural exports has negligible effects on the money supply, but a shock to agricultural prices is followed by a steady decline in the expected money supply. Money supply and agricultural price shocks have positive effects on expected agricultural exports, but these impacts are slight compared with a 1-standard-deviation export shock. The export shock has a positive effect on agricultural prices that peaks four quarters later at a level about equal to a 1-standard-deviation price shock. A money supply shock also positively affects agricultural prices peaking with a four-quarter lag, but the magnitude of this impact is small compared with the impacts of price and export shocks.

The figure shows the impulse response functions from the six-variable model. Each column indicates the responses of one variable over eight quarters to an initial 1-standard-deviation positive shock to each of the six variables. Thus, by looking down a column, one can assess the relative impact on a particular variable of various shocks typical of those estimated to have occurred during the sample period. For the interest rate, the value of agricultural exports, and the index of crop prices, the real effects of each shock are shown in the figure (that is, the simultaneous effects of each shock on the price level have been removed from their effects on the nominal values of these variables).

One can observe several aspects to the dynamic interactions among macroeconomic variables shown in the figure. A positive shock to the money supply declines slowly and steadily raises the price level. A money supply shock is also followed by a modest, but fairly persistent, rise in the interest rate. In contrast, an interest rate shock affects the expected interest rate for a relatively short period. It is followed by a decline in the money supply, a persistent appreciation of the U.S. dollar, and a lagged decline in the price level. Shocks to the exchange rate and the price level tend to persist, but have negligible effects on the money supply and the interest rate.[10]

The impulse response functions for the agricultural variables also show significant cross-variable interactions. In particular, the figure illustrates several macroeconomic impacts on agriculture. Money supply shocks have only small effects on the value of agricultural exports and relative agricultural prices, but an interest rate shock has an effect on exports which peaks with a magnitude about 50 percent of that of an export shock itself. An interest rate shock has a somewhat larger lagged effect on agricultural prices.[11] Shocks to the price level also noticeably affect agriculture. An unexpected increase in the price level has a strong negative effect on relative agricultural prices.

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[10] The contemporaneous correlation between shocks to the interest rate and the exchange rate is 0.45. Thus, it is probably appropriate to view these two variables as jointly representing financial markets. Specific effects attributed to one or the other of these variables should be interpreted cautiously. For example, the decomposition of forecast error variance shown in table 3 and the impulse responses shown in the figure suggest that interest rate shocks have substantial effects on the exchange rate. If the exchange rate is placed ahead of the interest rate in the orthogonal order, however, the proportion of exchange rate forecast error variance 12-quarters-ahead which is explained by own shocks rises to 70.5 percent, whereas the proportion explained by interest rate shocks falls to 6.3 percent. Likewise, the response of the exchange rate to an interest rate shock is dampened considerably. Other dynamic interactions among the macroeconomic variables remain similar to those displayed in the figure, although the effect of an exchange rate shock on the price level is greater.

The dynamic interactions displayed in the figure have several implications in terms of the alternative views of macroeconomic-agricultural linkages. Except for the fairly large effect of a money supply shock on the interest rate, there is only slight evidence of direct impacts from the money supply on either the financial market variables or the agricultural sector variables. If one views the money supply variable as a policy instrument of the monetary authorities, then the empirical results show little evidence that monetary policy affects agriculture.[12] Direct effects on agriculture of shocks to financial variables, particularly the interest rate, are more evident.

One possibility is that financial variables are very sensitive to expectations and move quickly in response to a shift in monetary policy. If changes in monetary policy are correctly anticipated and if these expectations are reflected in shocks to the financial variables before they are reflected in reported monetary aggregates, then monetary policy could still be the driving force behind the observed data patterns. This possibility requires that anticipated monetary policy have real effects, a proposition consistent with the fixed-price/flex-price macroeconomic model, but not with the stochastic equilibrium model. Furthermore, this view suggests that particular dynamic patterns should appear in the data. For example, an increase in the interest rate that correctly reflects an anticipated tightening of the money supply should be followed by such tightening and, perhaps, by a decline in the rate of inflation. Failure to observe these results has caused some macroeconomic studies to reject this possibility (*17, 26*). However, responses to interest rate shocks in some macroeconomic studies (*9*) and responses to interest rate and exchange rate shocks in the figure support this interpretation.

With respect to the general price level, the impulse responses shown in the figure do not suggest that price-level shocks arise in response to anticipated monetary policy (that is, the figure does not suggest that anticipated monetary expansion causes prices to rise now). Price-level shocks are not followed by changes in the money supply, and they cause relative agricultural prices to fall without an initial increase. These results are consistent with the view that autonomous price increases in nonagricultural sectors place agriculture in a cost-price squeeze, but not with the notion of monetary-induced inflation and overshooting of flexible agricultural prices (in which case one might expect a positive price-level shock to be associated with an initial increase in relative agricultural prices and to be followed by an increase in the money supply).

Finally, with respect to agriculture as a source of instability in the overall economy, neither the decomposition of variance nor the impulse response functions from the six-variable model demonstrates substantial macroeconomic impacts arising from the agricultural export and price variables. These outcomes are not altered appreciably when the agricultural variables are placed before the macroeconomic variables in the orthogonal order. This result suggests that macroeconomic-agricultural linkages are primarily from macroeconomic developments to agriculture, not vice versa.

Conclusions

The relationships among monetary and agricultural variables have been at the center of recent discussion of macroeconomic impacts on agriculture. Even so, definitive empirical evaluation of specific linkages has remained elusive. In this article, I have specified three- and six-variable VAR models and evaluated interactions among the money supply, the interest rate, the exchange rate, the general price level, and agricultural exports and relative prices.

The results suggest that there may be good reason for the ambiguity that characterizes discussion of

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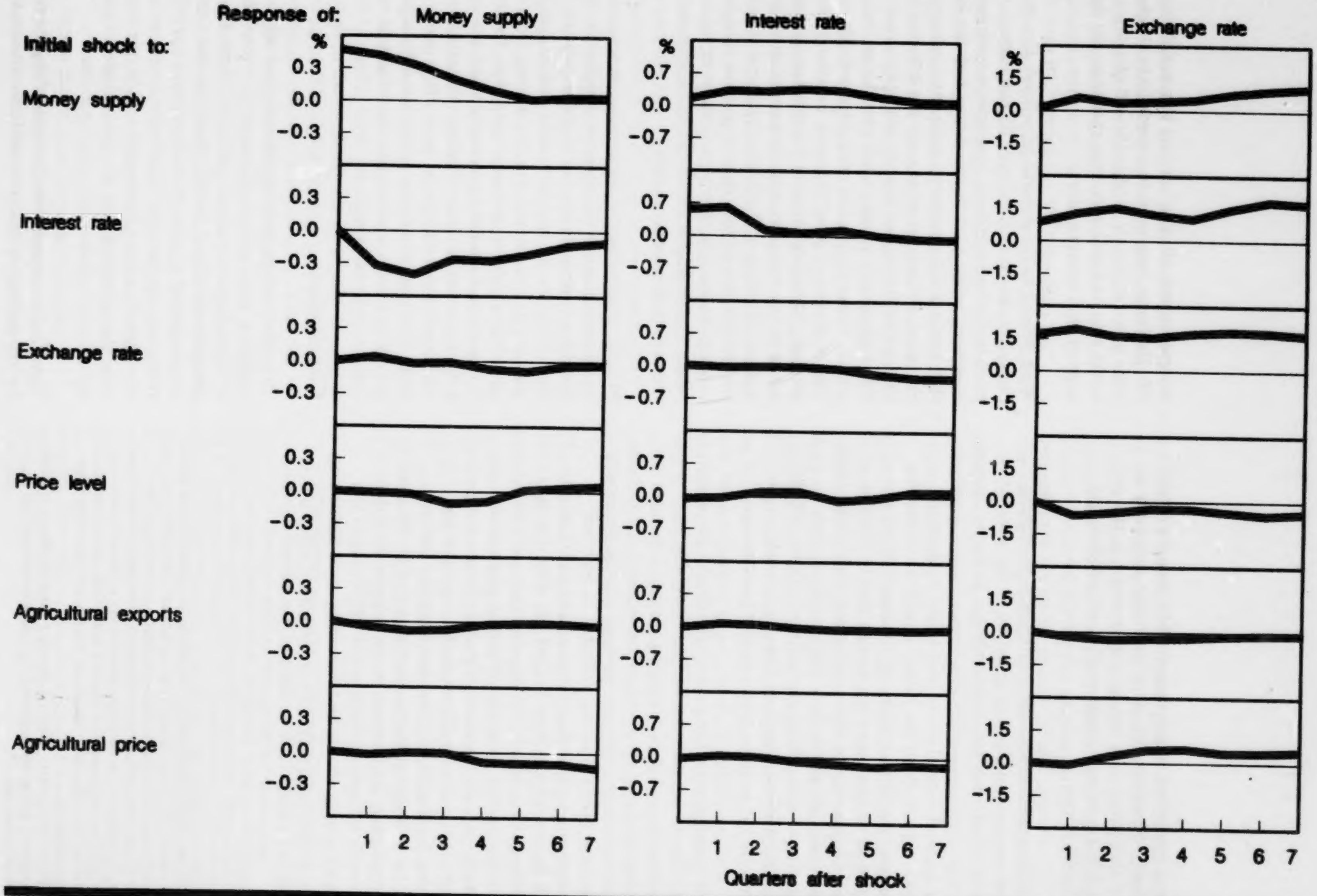
[11] In the results displayed in the figure, an exchange rate shock has a small effect on agricultural exports and little effect on agricultural prices. Again, these results are sensitive to the orthogonal order. When the exchange rate precedes the interest rate, the effects of an exchange rate shock on the agricultural variables exceed those of an interest rate shock. An unexpected appreciation of the dollar depresses subsequent agricultural exports and prices.

[12] Somewhat greater effects of money supply shocks on relative agricultural prices are suggested by a model estimated in deflated terms (see *19*).

Impulse Response Functions, Six-Variable Macroeconomic-Agricultural Model



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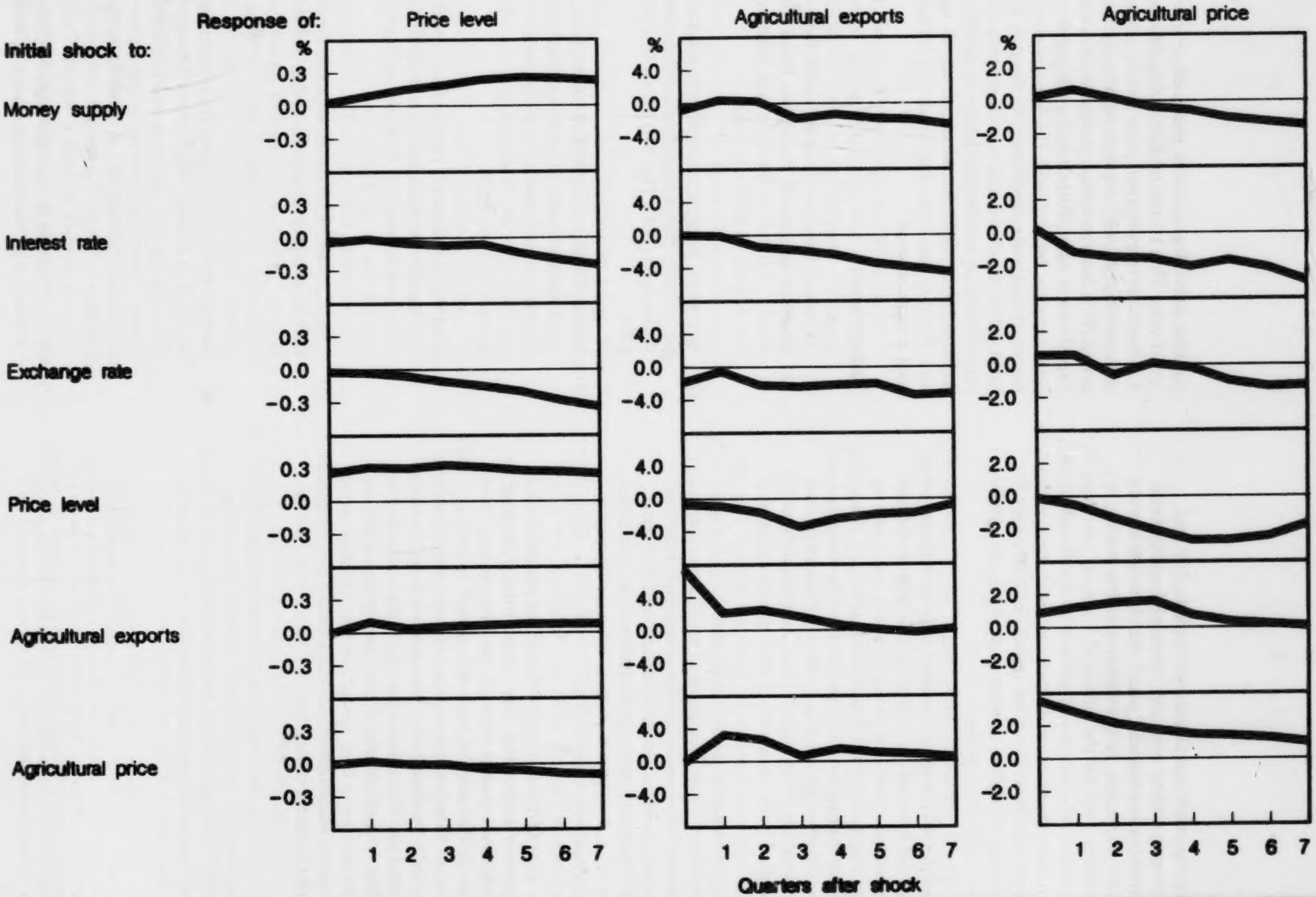
Impulse Response Functions, Six-Variable Macroeconomic-Agricultural Model



macroeconomic-agricultural linkages. Several linkages among macroeconomic and agricultural variables are isolated, and a number of these are quite important. In particular, there is strong evidence both for the effects of financial variables on agricultural exports and prices and for the effects of autonomous changes in the price level. In contrast, there is little evidence of impacts on the macroeconomic variables arising from shocks to agricultural exports or prices.

Specific shocks are associated with specific variables in a VAR model. Interpreting the results of these models as a basis for policy analysis must rest on this association of errors and variables, on the ability of policymakers to manipulate specific variables, and on such manipulation not affecting the estimated parameters of the model. One interpretation of the results I have presented is that shocks associated with financial markets (that is, the interest rate and the exchange rate) are independent of policy intervention. From this point of view, monetary policy does not have powerful effects on agricultural exports or relative prices. Autonomous financial market shocks have greater effects on agriculture, but are not subject to control by macroeconomic policymakers.

An alternative interpretation of the results is that monetary authorities may induce interest rate or exchange rate shocks through the instruments they control. This control could be exerted directly or because changes in monetary policies affect financial market variables before they are recorded in money stock data.[13] In either case, the impact of monetary policy on agricultural exports and prices would be more pervasive than under the first interpretation. Dynamic responses in the VAR model are consistent with the latter possibility.

This point is clear when one applies similar considerations to the price-level variable. Price-level shocks could also reflect monetary decisions. In that case, one would expect an increase in the price level to affect agricultural prices like a decline in the interest rate. This situation does not occur, suggesting a different interpretation: price shocks not associated with monetary policy depress relative agricultural prices. This interpretation is consistent with the hypothesis of agriculture's being caught in a cost-price squeeze, but not with the hypothesis of monetary-induced overshooting of flexible agricultural prices. Such an outcome does not fit easily into recent analysis of the disinflationary effects of tight monetary policy and its specific effects on agriculture. Even so, the data display strong evidence of such a phenomenon.

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[13] Litterman treats the Federal funds rate as an indicator of monetary policy and evaluates the impacts of changes in this rate on the money supply, other financial variables, and the real economy (*16*). A change in the Federal funds rate is assumed to affect the 3-month Treasury bill rate, stock prices, and the value of the dollar contemporaneously, but to affect the money supply only after a 1-month lag.

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Nonfarm families typically have higher money incomes than farm families but lower net worths. Considerable public money is channeled into the farm sector via farm commodity programs, directly affecting the level of well-being as measured here. Economists often argue that many of the benefits from farm programs get capitalized into land values and thus may affect the level of net worth more than money income. This is because benefits are tied directly to land resources rather than family need. If these programs were expanded until the level of money income of farm families equaled that of nonfarm families, the economic well-being of farm families might well exceed that of the nonfarm group. From society's point of view, it may be more desirable to provide direct income support to families in the farm sector than to further enhance the level of net worth.

Thomas A. Carlin
July 1973, Vol. 25, No. 3

Research Review

Crop Insurance for Agricultural Development: Issues and Experience

Peter Hazell, Carlos Pomareda, and Alberto Valdés (eds.).
Baltimore: Johns Hopkins Press, 1986, 322 pp., $32.50.

By David Freshwater and David Trechter*

Many countries operate "multi-peril" crop insurance programs to compensate participating farmers when various environmental factors cause low yields. This book leaves one with the overwhelming impression that multi-peril crop insurance has been an expensive failure. The book, although primarily oriented toward crop insurance programs in developing countries, also examines crop insurance in developed economies. In both environments multi-peril crop insurance has received large government subsidies, serviced a limited clientele, and had marginal success in stabilizing farm income. This book addresses both theoretical arguments for establishing crop insurance (including potential impacts on producer and lender incentives) and historical experiences with such insurance. Roughly half the book has a theoretical or conceptual focus; the other half is devoted to case studies of particular programs.

Although each chapter is written by a different author or authors, the editors have done a good job of referring the reader to other chapters containing relevant material. The introductory and concluding chapters, written by the editors, provide a useful overview and briefly summarize major arguments and conclusions. Anyone with even a passing interest in the economics of multi-peril crop insurance should read these chapters.

The book has several shortcomings. The papers are grouped into three parts, one focusing on demand for crop insurance, one dealing with insurance as a policy instrument, and one examining the operation of selected crop insurance programs. The part examining insurance as a tool for policy is by far the least successful. It is not clear why some of the chapters are even in this section. In particular, the chapters on crop insurance programs in Mexico and Japan might better have been placed in the empirical part of the book. The biggest disappointment of this section, however, is that it fails to deal positively with the shortcomings of crop insurance. If crop insurance is a flawed tool, what changes could be made to improve its performance? If it is an inappropriate policy tool, are there alternatives that address the same objectives? The authors address such questions, if at all, in a superficial and unconvincing way. For example, the conclusion of the chapter analyzing Mexico's program states that crop insurance "increases incomes and employment in the farm sector and prevents a decline in aggregate production. Perhaps these effects might more simply be attained through price policy." But is this alternative politically feasible? Can a price policy also address other problems, such as stability of income or improved access to credit, which motivate crop insurance programs? The authors generally prefer to list alternatives without submitting them to the same degree of scrutiny given to the crop insurance program.

The other sections of the book are more successful. The authors tend to focus on a few common themes: (1) crop insurance works best as a mechanism to stabilize farm income when the principal factor affecting income is yield fluctuations; (2) multi-peril crop insurance schemes are expensive to operate and subject to moral hazard and adverse selection;[1] and (3) subsidized crop insurance programs may provide net social benefits, but may not be the most efficient means of achieving social goals. Conversely, crop insurance programs are considered useful in well-defined contexts, such as insuring yields against specific natural hazards. This technique can also be an effective way to foster the development of credit for farmers, since it protects lenders against a major cause of borrower default, particularly if the lender receives the crop insurance payment directly.

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*The reviewers are agricultural economists with the Agriculture and Rural Economics Division, ERS.

[1] When insurance coverage alters a policyholder's incentive structure such that outcomes involving losses are encouraged, a moral hazard exists. Adverse selection arises when farmers with higher than average risks comprise a larger share of the insurance pool than forecast when premiums were set.

Those with an interest in U.S. agriculture will find the chapter by Gardner and Kramer particularly useful. It gives an account of the development of the U.S. crop insurance program, summarizes previous studies of program impacts, and analyzes demand for crop insurance and its influence on farmer behavior. Other chapters use U.S. examples in their analysis. In his chapter on the financial viability of agricultural insurance, Pomerada examines the U.S. experience in terms of administrative costs, indemnity to coverage ratios, and other operating variables.

By focusing attention on all-risk crop insurance and the problems encountered with its use in developing countries, the book leaves the impression that crop insurance is a flawed tool. However, the inevitability of this conclusion is unclear. Many problems described in the book arise either because crop insurance is asked to serve a function for which it is not well suited or because the information necessary for successful implementation is not available. The book does contain much useful information. Better organization and a more comprehensive analysis in the policy section would have enhanced it greatly.

Instead of mounting surpluses, increasing storage costs, and Treasury expenditures for farm commodity programs, rising consumer food costs have become a principal concern of people interested in U.S. agricultural policy. Associated with this changed emphasis is a renewed interest in foreign trade policy for agricultural commodities and the effects of liberalized trade on the U.S. food and fiber sector of the economy.

James Vermeer, David W. Culver,
J.B. Penn, and Jerry A. Sharples
April 1975, Vol. 27, No.2

Linking Macroeconomic and Agricultural Policies for Adjustments with Growth: The Colombian Experience

Vinod Thomas and others. A World Bank Publication. Baltimore and London: Johns Hopkins Press, 1985, 252 pp., $32.50.

Reviewed by H. Christine Bolling*

The author and his collaborators are the World Bank's "old hands" on Colombia's economy and have produced several excellent World Bank reports. Using material taken from some of these publications, the authors have presented a study that is both a technically excellent and very readable account of Colombia's macroeconomic and agricultural policies and their effects. Any students of Colombia's agriculture should read this book.

The authors make several background points:

- Colombia has a relatively small modern sector superimposed on a broad traditional base. It produces more than 90 percent of its own food, and agriculture is still a major industry.

- Nearly half of Colombia's legal foreign exchange earnings are from coffee exports. Colombia has diversified from coffee to protect itself from the wide swings characteristic of a primary product economy. [But, in 1986, coffee will again provide the windfall foreign exchange earnings that will pull Colombia out of its current economic slump. Colombia's economic boom of the late seventies was also due to a runup in international coffee prices.]

- Colombia has a low foreign debt at a time when its neighbors, both rich and poor, have suffered the consequences of carrying a large debt load. Colombia's current debt situation is largely attributed to its conservative import policy.

- Colombia is a textbook case for policymakers because, at one time or another, the Government has tried nearly every type of intervention: exchange rate manipulation, import taxes, export taxes, export subsidies, import licensing, and price controls through the Instituto de Mercadeo Agropecuario (Agricultural Marketing Institute (IDEMA)).

The book provides an analytical account of Colombia's policies. Some of the problems that Colombia has had to deal with are universal to developing countries: devaluation, inflation, and the vagaries of primary product markets. Because Colombia has gotten through these problems more successfully than most developing countries, its experiences may be an object lesson to others.

The authors stress that policymakers cannot make agricultural policy in isolation, nor can the macroeconomic policymakers ignore the effect their decisions have on the farm sector. They often must make tradeoffs among sectors, and they may find themselves in a web of offsetting policies.

In the chapter on export policy, the authors cover exchange rate management (through the "crawling peg" exchange rate), export loans, and subsidies. They conclude that Colombia has benefited more from an export-oriented policy than from import substitution.

In the import policy chapter, the authors develop a rationale for import tariffs and licensing. They then show how these instruments cause increased domestic prices, inefficient allocation of resources, and losses in consumer welfare. They also show the tradeoffs among policies. For example, higher tariffs are used to compensate for overvaluation of the peso. With a higher tariff, the importable sector grows partly at the expense of the exportable sector. Moreover, increases in protection tend to depress overall economic activity. The authors also note that trade liberalization should proceed in stages to reduce short-term dislocation (many policymakers choose to ignore this point).

The latter chapters pertain specifically to agriculture. The authors use the price intervention chapter to discuss the role of IDEMA in Colombia's agricultural price-support program.

The chapter on price stabilization is less country-specific. Although price stabilization is a goal of Colombia's agricultural policy, the authors say that it is often unclear whether Colombia's policies stabilize prices, incomes, or some other economic factor. Price stabilization may bring other problems: distortions in production incentives and a failure to react to price signals in world markets.

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*The reviewer is an agricultural economist with the International Economics Division, ERS.

Coffee gets a special chapter because of its importance to Colombia's economy. Although coffee exports raised export earnings, these windfall earnings had to be carefully managed to avoid excessive inflation. The authors discuss current coffee production technology and the policy issues specific to coffee: export taxes, mandatory deposits of export receipts in the Central Bank, stock and price policy, and diversification programs.

Other chapters include Government expenditures on agriculture and input policies. Finally, the authors sum up how these policies, whose aim is "to bring about economic adjustment while sustaining growth," are faring. They show what policy issues Colombia will face in the near term.

The authors have written this book cleverly. Although they use empirical studies, they leave the mathematical modeling for the appendixes and footnotes. Several of these appendixes are worthy of mention. Appendix A showcases economic models that support the authors' conclusions on the interaction of coffee prices, money supply, and inflation in Colombia. Models in appendix B illustrate how changes in international coffee prices affect the competitiveness of coffee with other import goods and nontradables in Colombia.

Appendix C contains a model for predicting nominal interest rates in a semi-industrialized, semi-open country like Colombia with explanatory variables of money supply, real income, expected devaluation of the domestic currency, and a risk premium term. Appendix F details Colombia's marketing system for coffee, emphasizing the price mechanism and coffee taxes. Other appendixes graphically present the welfare cost of price stabilization and measure variability in international, producer, and consumer prices, producer gross incomes, and net profits for nine crops.

The book has a few minor weaknesses. In discussing protection and efficiency (p. 68), the authors take the easy way out in the calculation of nominal rates of protection by comparing farm gate with international prices for several commodities and then by noting in the text how prices should be more precisely identified. The authors are long-time students of Colombian agriculture and presumably have more access to price, transportation cost, and marketing cost information than do most researchers.

One of the contributing authors states: "it is necessary to increase the real quantity of money, requiring that an increase in the rate of growth in nominal money not be matched by higher equiproportional inflation (pp. 190-91). This feat can be accomplished in the real world economy only in the very short run. Although the authors criticize the Colombian coffee industry for carrying too large a stock, the country will benefit from windfall profits from that stock. In early 1986, the Brazilian coffee industry suffered crop losses from drought, driving up international prices. Such is the fate of an author's putting prediction into print. These criticisms aside, the book is a worthwhile study of considerable breadth and depth.

Removal of Price Supports and Supply Controls for U.S. Tobacco: An Economic Analysis of the Impact

Daniel A. Sumner and Julian M. Alston, Washington, D.C.: National Planning Association, 1985, 60 pp. $8.00

Reviewed by Barbara Stucker*

Sumner and Alston have tackled a touchy subject: the consequences of removing price supports and supply controls for U.S. tobacco. The authors deserve credit for examining this sacred cow of farm commodity programs. In their own words, "Elimination or phasing out of the federal tobacco program would have impacts on the prices and quantities of several products and would significantly affect the income and well-being of millions of people." Their analysis does not address the social issues and controversy over the conflicting Federal policies of farm support and public health. Theirs is not a social assessment of a shift in policy away from price supports and supply controls; it is an economic analysis of the change in the well-being of producers, the tobacco industry, and exporters. The book analyzes changes in prices, supply, and demand for tobacco that might result if protectionism were abolished or reduced.

The book begins with an extremely brief description of the U.S. tobacco program. Fifty years of history are condensed to a single page. No criticism is intended here, simply an observation that the authors are anxious to get into the analysis without becoming bogged down in historical legislation. They concentrate on the current program and its operation. They explain supply controls and support prices with the right degree of depth to give the reader a good understanding of the tobacco program and its peculiarities, but not in such detail as to slow the reader down.

Tobacco is a peculiar crop, and that's what makes this economic analysis unique. The authors must unravel a tangle of restrictions on producing and marketing tobacco before they can assess the "good and bad" of deregulation. They begin by examining who owns production rights—that is, how many quota holders produce tobacco, as opposed to how many producers lease the right to raise tobacco. Patterns of ownership vary by State, as do lease rates, occupation of owners, size of quotas, and number of allotments.

The authors then continue to wave their economic wands over the tobacco sector, eliminating price supports here, withdrawing allotments there, and voilà: Equilibrium is achieved, production expands, prices fall, exports rise, demand increases domestically, efficiency is attained in least-cost regions, and industry revenues bulge. Areas of expansion are blessed with increased income, whereas losers experience the contractionary costs of dislocation and lost income.

Perhaps the hand is quicker than the eye in this case. Of course, a change in price vis-a-vis a reduction in price supports would affect supply and demand. So would freedom of production. These are not enlightening results. But the degree of change presented by the authors is of such magnitude that both their results and the questions raised by those results are worth mentioning here:

- An increase in tobacco production of 50-100 percent,
- A reduction in the price of tobacco of 20-30 percent,
- An increase of 100 percent in U.S. tobacco exports,
- An increase in the quantity of U.S. tobacco demanded by 50-100 percent, and
- An increase of 15-60 percent or more in total revenue to the tobacco industry.

Aren't any negatives associated with deregulation of the tobacco industry? Yes, the authors illuminate them as well:

- A loss of up to 2-3 percent in personal income in counties with a high dependence on income from quota ownership,
- Elimination of the capital value of tobacco production rights and the consequent loss of about $800 million in annual income to quota owners,

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*The reviewer is an agricultural economist with the National Economics Division, ERS.

- Major costs of dislocation and disruption if price supports and production restrictions were eliminated suddenly, and
- Some increase in price variability for tobacco relative to the 1950-80 period.

The results of the analysis elicit the question: why is deregulation dragging its feet, when the consequences seem to fit so well with current overall farm policy objectives? Despite the negative consequences associated with deregulation, they are negative mostly for landowners who, we should be reminded, are largely not the producers. Expansion in production that would be absorbed by regaining lost export markets is a dominant theme of farm policy in the eighties; here is a case where that policy could be successfully implemented.

The authors caution against immediate and swift deregulation for several reasons. First, postulating what the tobacco industry would look like in the absence of regulations is like painting a picture blindfolded. Tobacco has been regulated in varying degrees for more than half a century. No one can be sure of the results of deregulation, because no one has seen such an animal. It is no longer the tobacco industry of the thirties. Thus, the authors admit their confidence must be checked on this score.

Next, even if policymakers wished to redistribute wealth from nonfarming landowners to producers, the loss of wealth to individuals, to counties, and to regions which have come to depend on that wealth would be enormous, highly concentrated in a few areas, and devastating. Tobacco quota ownership is most concentrated in North Carolina, for example, providing over 5 percent of the State's total agricultural revenue. One county alone in North Carolina would, according to deregulation proposed here, lose $19 million, or about 14 percent of its total revenue from agriculture. When policymakers are faced with an equally pressing concern of alleviating financial stress, as they certainly have been thus far in the eighties, the gains from deregulation pale somewhat.

Still, the authors offer a compromise: phase out price supports and supply controls, if immediate deregulation is economically and otherwise unpalatable. The tradeoffs between slow and swift, they suggest, are smaller costs of disruption and smaller losses to quota owners at the expense of other people who would benefit from immediate elimination.

This book concludes with two reviews: one from a representative of the tobacco industry (James H. Starkey, Vice President of Universal Leaf Tobacco Company, Inc.), the other from a veteran agricultural economist (Harold F. Breimyer). Although both reviews commend the authors for their undertaking, the reviewers less than fully embrace the results of tobacco deregulation. Starkey suggests that the single biggest problem with the tobacco program is price, which has hampered the ability of U.S. tobacco to compete in world trade and led to disillusionment with the tobacco program on all fronts. Breimyer concedes the problems of the tobacco program, but also admits remembering the pre-1933 years, when "tobacco farmers were probably agriculture's poorest in the years just before the program began. Tobacco production was the refuge of the impoverished. Entry was so easy, jobs so scarce, and acreage so expandible." Breimyer concludes, as does this reviewer, that by exploring various issues in program-making for tobacco, Sumner and Alston have provided a useful service. Given the path on which U.S. agriculture is currently headed, policymakers can only welcome analyses that consider changes in farm commodity programs designed to speed agriculture on its path to recovery and strong performance in the years ahead.

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In This Issue

In the Fall 1985 issue, this column discussed Lawrence J. Peter's tongue-in-cheek definition of an economist as "an expert who will know tomorrow why the things he predicted yesterday didn't happen today." Peter was needling the economics profession for its after-the-fact handling of economic problems. This column pointed out that, in spite of the apparent surface truth of his observation, economics is not a precise profession and its practitioners daily risk professional reputations by making economic analysis on less than complete information.

In this issue we have several examples of professional courage. In the research review section, Tweeten revisits a statement he made in this journal in July 1980: "I contend current land prices can be justified by prospective earnings." Time and economic events have not been kind to this statement. Land prices did continue to rise until 1982, but have since fallen 28 percent. In a reappraisal of his 1980 statement, Tweeten is in a sense carrying the ball for the agricultural economics profession because his assessment of the farmland market was not an uncommon view. So read "A Note on Explaining Farmland Price Changes in the Seventies and Eighties." Was our inability to foresee the significant drop in land prices due to faulty economic theory and analysis or due to events outside our control or ability to foresee?

In contrast to the economist with an established reputation exhibiting the courage to review a past statement that subsequent events did not support are economists Shoemaker and Somwaru, who are early in their careers. They exhibit the professional courage to present results that may differ from conventional wisdom about the cost and productivity structure of U.S. dairy farms. They apply total factor productivity, a somewhat more comprehensive technique than often used in past productivity measurements, to analyze a recently available data series, the Census of Agriculture Standard Industrial Classification (SIC) type of farm data. They examine this series for the implications of regional differences in productivity levels and for changes in dairy farm productivity. Their article deserves thoughtful reflection as this technique and this data source are hard to ignore. Total factor productivity based on a national income and product accounting-type framework imposes an accounting discipline on the productivity analyst that may require answering questions that never occur to users of other approaches. The Census type of farm data is also hard to ignore. These data are summaries of the census of the actual dairy farms that make up our national dairy sector. If results based on these data run counter to intuition or conventional wisdom, one has to wonder why.

Finally, Smallwood and Blaylock assume the risk of communicating a very econometrically oriented discussion of modeling issues concerning short-term forecasting to the readership. The topic is more technical than the usual AER article, and they undertake the task of writing at a level that will encourage wider readership while maintaining technical content and professional quality.

Gerald Schluter

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Total Factor Productivity and Sources of Growth in the Dairy Sector

Robbin Shoemaker and Agapi Somwaru

Abstract

One would expect to find differences in total factor productivity (TFP) associated with factor allocation, given the technological change in the dairy sector over time and the regional disparity of regulations affecting production. The authors use a National Income and Product Accounting procedure to calculate total income and product, TFP, and sources of growth for seven dairy States in different regions. The average TFP growth for the seven States was 2.5 percent per year. Florida and California had higher TFP *growth* rates, but interspatial TFP estimates indicated Wisconsin and New York had greater relative TFP *levels* in both 1978 and 1982.

Keywords

National Income and Product Accounting, intertemporal and interspatial total factor productivity, rates of return, sources of growth

One would think the dairy industry is fairly diverse regionally. There has been considerable regulation of milk pricing and production within the dairy sector, but these regulations have differed markedly across regions, primarily because of Federal marketing orders, subsidized pricing, and different State-level effects of price-support programs. Such regional differentiation of regulations within an industry leads one to expect differences in factor returns, allocations, and productivity by region. Total factor productivity (TFP)—changes in output for a given level of total input—is usually associated with technological change or more efficient reallocation of a given level and quality of inputs. In this article, we examine TFP differences across regions within the dairy sector.

Productivity measures at the firm level are usually based on detailed enterprise data. These measures are often estimated as yield per acre or pounds of milk per cow. Insufficient data for performing the analysis on a milk-per-cow basis limited this analysis to the three-digit Standard Industrial Classification (SIC) of the dairy sector. Furthermore, since a productivity measure such as pounds of milk per cow can provide a biased measure of productivity, a TFP index measure of productivity growth is useful because it corresponds more closely to a production function; that is, the TFP index relates output to an implicit function of all inputs (*5*).[1] Although the index number approach is relatively simple to implement, it assumes uniform technical parameters across all regions, whereas those regional parameters can be estimated with an econometric approach.

We applied the analysis to seven regionally diverse dairy States: Pennsylvania, New York, Vermont, Wisconsin, Florida, California, and Texas. These States were selected as representative of diverse dairy-producing regions because their herd sizes and input costs differ considerably.

We provide some insight into the relative productivity of these different regions by using a National Income and Product Accounting (NIPA) procedure. These accounts provide a method consistent with the economic theory of production and income. We

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[1] Italicized numbers in parentheses refer to References at the end of this article.

use a procedure first proposed by Kendrick and Jones (*12*) in setting up the national agricultural income and product accounts. This method is used to derive gross national product at the national level where output (total product) is the final value of all goods and services at market prices. Income is the payment to all factors (that is, capital and labor). We chose this method because it enables us to account for all income and products in the dairy sector. The estimates of real factor payments and output allow us to calculate the difference between the growth in output and inputs, which is used to indicate productivity growth.

The NIPA method provides an accounting system with *all* inputs and outputs captured in a closed system; that is, all variables are defined such that total value of all factors is equal to the total value of output. Thus, we implicitly assume that dairy production is characterized by constant returns to scale, an assumption that may not apply to the dairy sector, but which cannot be tested in this type of analysis.[2] As a closed system, the procedure is complete in that it requires an accounting of all relevant variables. The requirement imposed by our analysis is no less a problem than it is for construction of the national accounts. However, for a particular sector, this type of accounting implies that the results regarding the sector's performance may be more suggestive than conclusive. Developing an income and product account of an economic sector is useful because it logically identifies key economic variables of that sector: gross product (value-added output), profit income (net farm income), property compensation, and rate of return to capital. By converting the value-added measure of output to a gross measure by including intermediate products and by estimating the service flows of capital, labor, and materials, one can estimate TFP. Using the estimates of the growth in factor inputs, outputs, and TFP, one can determine the sources of growth in output between the growth in factor inputs and technological change. We made regional comparisons for 2 census years, 1978 and 1982, and we calculated TFP levels and growth rates for this 5-year period.

In this article, we develop dairy-sector income and product accounts for the constant-dollar SIC, and we discuss regionally diverse incomes and returns. We derive aggregate productivity estimates. Finally, we perform a sources-of-growth analysis to quantify factors contributing to differences in the output growth across regions.

Income and Product Accounts

We first develop the income and product accounts for the SIC dairy farms. These accounts for the seven States are set up in both current and constant 1977 dollars for 1978 and 1982.

The Census of Agriculture classifies farms by two- and three-digit SIC codes at national and State levels. Farms where dairy products account for 50 percent or more of total farm sales are classified as three-digit SIC dairy farms. Income and product estimates reported here are based on data from the Census of Agriculture as used by Somwaru (*14*).

The derivation of dairy income and product follows the procedure used for the Gross Farm Product and Income account (*9, 12*) by the Bureau of Economic Analysis of the U.S. Department of Commerce. Total value of output is the sum of crop and livestock receipts (including net Commodity Credit Corporation (CCC) payments), Government payments, and income from custom work, rentals, and recreational services (tables 1 and 2). Including Government payments may be problematic because these payments may increase while actual production is constant, thus giving a policy-distorted increase in total output. When this potential distortion in total returns affects the allocation of inputs, including Government payments certainly is valid. The imputed value of home consumption of farm products and the change in crop and livestock inventories are included in other income.

One derives gross dairy product by subtracting the costs of intermediate products (feed, seed, energy, fertilizer, and so forth), custom work, rent, and repairs from total output. This figure yields the value-added measure of output for the dairy sector; that is, it contains the value of all dairy and nondairy products produced by the sector net of intermediate products that contribute to dairy produc-

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[2] One makes several assumptions when using a NIPA framework. First, the longrun competitive price-taking behavior of producers is associated with profit maximization. Next, the SIC delineation of the dairy sector implies that firms are multiple-output producers. Furthermore, one assumes a constant-returns-to-scale multiple-output transformation function and that value-added output implies that production is separable from intermediate inputs.

Table 1—Gross dairy product and income, constant 1977 dollars, 1978

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
Crop cash receipts:							
Grain	24,509	62	405	62,020	2,816	11,688	1,953
Cotton and cottonseed	0	0	0	0	14,548	0	407
Tobacco	5,300	0	239	5,657	0	0	0
Field seeds, hay, forage, and silage	15,215	876	200	23,898	4,956	9,995	679
Vegetables, sweet corn, and melons	1,673	116	468	8,430	1,738	2,645	82
Fruits, nuts, and berries	362	130	299	320	7,976	1,371	43
Nursery and greenhouse products	215	5	165	56	0	56	0
Other crops	662	12	211	684	1,070	343	729
Livestock cash receipts:							
Poultry and products	3,425	58	390	2,011	5	910	132
Dairy products	748,321	224,605	229,643	1,854,628	1,150,241	1,026,498	351,657
Cattle and calves	59,881	14,070	16,899	170,221	78,381	72,831	28,760
Hogs and pigs	5,893	70	183	36,856	247	789	504
Sheep, lambs, and wool	150	17	0	303	143	102	169
Other livestock	385	67	74	461	119	280	70
Government payments	2,262	261	45	4,571	2,160	1,536	2,541
Custom work	3,826	250	65	10,204	2,614	2,704	1,519
Rents	419	153	154	1,536	334	640	502
Recreational services	2,348	532	85	6,862	456	2,569	511
Other income:							
Home consumption	7,161	1,601	214	21,014	1,339	7,820	1,387
Change in inventories:							
Crops	15,750	1,047	558	35,274	7,893	10,322	1,608
Livestock	(16,511)	(4,777)	(4,965)	(41,941)	(24,633)	(22,104)	(7,686)
Total value of output	881,246	239,155	245,332	2,203,085	1,252,403	1,130,995	385,567
Intermediate expenses:							
– Intermediate products	277,562	93,596	124,674	565,393	555,006	402,995	179,970
– Custom work expense	7,820	882	726	20,343	11,975	7,042	2,728
– Rent expense	11,970	3,350	1,108	26,981	3,389	15,223	7,322
– Repairs	58,057	13,764	2,564	179,142	15,937	69,798	10,135
– Other expenses	23,884	6,941	6,999	56,613	30,963	31,368	10,831
= Gross dairy product	501,953	120,620	109,261	1,354,613	635,133	604,569	174,581
– Capital consumption	133,978	31,763	5,917	413,403	36,777	161,072	23,388
– Property taxes	18,767	3,449	2,097	40,628	8,592	14,361	4,608
= Income originating	349,208	85,408	101,247	900,582	589,764	429,136	146,585
– Labor compensation	47,052	16,185	24,043	93,692	84,817	71,564	22,257
= Property compensation	302,156	69,223	77,204	806,890	504,947	357,572	124,328
– Net interest	55,256	13,964	15,109	116,491	64,091	59,480	23,338
= Net farm income	246,900	55,259	62,095	690,399	440,856	298,092	100,990

Numbers in parentheses denote negative values.

Table 2—Gross dairy product and income, constant 1977 dollars, 1982

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
Crop cash receipts:							
Grain	34,715	346	465	112,506	5,559	23,005	3,641
Cotton and cottonseed	0	0	0	0	27,629	0	0
Tobacco	5,632	0	0	5,589	0	0	0
Field seeds, hay, forage, and silage	5,982	1,724	470	10,604	8,744	5,927	1,488
Vegetables, sweet corn, and melons	2,156	105	0	9,540	2,102	3,039	202
Fruits, nuts, and berries	328	98	1,057	215	5,442	1,138	304
Nursery and greenhouse products	190	11	0	60	0	52	0
Other crops	1,233	12	352	1,303	1,150	624	1,135
Livestock cash receipts:							
Poultry and products	3,876	130	463	1,639	5	1,020	334
Dairy products	831,969	242,399	254,291	2,146,801	1,403,769	1,092,155	370,677
Cattle and calves	58,515	14,543	17,175	186,709	89,615	66,357	27,244
Hogs and pigs	5,396	60	181	31,190	679	595	735
Sheep, lambs, and wool	112	19	0	319	88	126	34
Other livestock	483	119	4	583	83	314	172
Government payments	2,192	325	135	5,385	1,479	2,138	577
Custom work	5,648	558	42	14,921	4,560	3,734	1,626
Rents	264	77	37	900	231	209	317
Recreational services	2,148	471	62	6,278	417	2,350	467
Other income:							
Home consumption	5,953	1,308	130	17,228	1,114	6,144	1,054
Change in inventories:							
Crops	(10,873)	(463)	(466)	(26,601)	(7,059)	(6,438)	(1,239)
Livestock	(8,023)	(2,257)	(2,391)	(20,964)	(13,131)	(10,189)	(3,516)
Total value of output	947,826	259,585	272,007	2,504,205	1,532,476	1,192,300	405,252
Intermediate expenses:							
– Intermediate products	245,700	83,865	108,296	652,172	581,628	370,994	158,451
– Custom work expense	1,563	210	128	4,099	3,557	1,218	430
– Rent expense	10,036	2,439	810	24,311	3,005	11,526	5,415
– Repairs	49,345	11,331	2,365	156,261	14,636	58,492	9,243
– Other expenses	42,499	9,957	9,681	95,927	50,136	45,535	15,205
= Gross dairy product	598,683	151,783	150,727	1,571,435	879,514	704,535	216,508
– Capital consumption	127,824	29,352	6,127	404,787	37,914	151,521	23,943
– Property taxes	18,515	3,409	2,102	44,792	12,526	13,759	5,289
= Income originating	452,344	119,022	142,498	1,121,856	829,074	539,255	187,276
– Labor compensation	48,754	19,232	26,764	113,397	99,622	86,214	22,107
= Property compensation	403,590	99,790	115,734	988,459	729,452	453,041	165,169
– Net interest	104,996	22,413	22,550	228,516	119,716	94,003	38,159
= Net farm income	298,594	77,377	93,184	759,943	609,736	359,038	127,010

Numbers in parentheses denote negative values.

tion. Subtracting capital consumption allowances and indirect business taxes (property taxes) from gross dairy product yields income originating in the dairy sector. Income originating in the sector is defined as the sum of all factor payments (that is, all payments to capital and labor); therefore, subtracting labor compensation yields property compensation or income earned by capital. Finally, property compensation less net interest (payments less receipts) yields sectoral net farm income or profit.

One derives constant dollar estimates of income and product by deflating separate components of the account by the respective prices received and paid by farmers using 1977 as the base year. For example, grain is deflated by the index of prices received for food grains. Cotton and cottonseed are deflated by the index of prices received for cotton and so on.[3] These deflators come from the *Agricultural Prices* annual summary (*18*). Because item-specific regional deflators are not available, the deflators used reflect national prices and are applied to all States.

Income and Returns

Using the gross dairy income and product account, we can derive some indicators for the sector's performance, including TFP growth and the capital-labor and capital-output ratios. The latter two ratios are of interest because they indicate relative factor intensity. We are interested primarily in the rate of return to capital. One can calculate this rate in each period by dividing the constant dollar value of property compensation (income from capital) by the constant dollar value of total capital stocks. This quotient yields capital income as a percentage of the value of capital stocks, that is, the amount of income flowing from capital stocks. The percentage is a real rate of return in the sense that it is derived as a ratio of constant-dollar-valued income and capital stocks.

This rate is used to calculate capital services. Because we do not have a direct measure for the rate at which capital is used, as we have for the hours of labor services, we must convert the stock of capital to a flow of capital services. Capital services are calculated as the product of the rate of return to capital and the weighted sum of capital stocks where the weights are the portions of each component of capital to the total.[4]

Capital stocks include land and structures, machinery and equipment, livestock inventories, and crop inventories. The current dollar value of land and structures and that of machinery and equipment valued at market prices are taken from the Agricultural Census. We derived constant dollar values of these capital stocks by deflating each component of capital by its respective price index (see the appendix for the list of deflators). Constant dollar livestock inventories are calculated from Census numbers of head times the price index for livestock. We derived crop inventories from State balance sheet data (*16, 17*) and prorated them to the SIC dairy sector using Census benchmarks (table 3). We measured producer durables (machinery and equipment) gross of depreciation because, given repairs and maintenance, the productive capacity of the equipment will endure (*11*).

In 1978, California received more than twice the rate of return (16.7 percent) as did the northern States. Florida and Texas also had rates greater than the northern States, receiving 11.8 percent and 9.2 percent, respectively. Pennsylvania, Vermont, Wisconsin and New York had similar rates. In 1982, both Florida and California had rates near 20 percent, suggesting a considerable growth in income and a potential underinvestment in capital. The return to capital increased in all northern States, but increased the least in Wisconsin.

These returns imply that operations in California and Florida earn a higher rate of return to more capital-intensive operations (in terms of the capital-output ratio) than do the smaller operations of the northern and Lake States. However, the reasons for these high returns in California and Florida differ. For example, Florida had high-valued returns because it received the benefit of the highest

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[3] The specific items and their deflators appear in the appendix.

[4] One usually formulates the capital service price following Hall and Jorgenson (*8*):

$$p_t = q_t(r_t + d + T_t - g_t)$$

where q_t is the acquisition price, r_t is the rate of return, d is the depreciation rate, T_t is the tax rate applied to capital, and g_t is capital gains. We did not use this method for several reasons, chiefly because we lacked the data to support this method. Furthermore, we gained no additional information in our limited attempt to use this formula.

Table 3—Constant 1977 dollar capital stocks and rate of return to capital, 1978 and 1982

Year and item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
1978:							
Land and structure	3,602,362	662,014	402,650	7,798,694	1,649,246	2,756,702	884,634
Machinery and equipment	668,287	158,435	29,514	2,062,073	183,446	803,434	116,661
Livestock inventories	719,618	209,149	216,893	1,824,302	1,077,285	965,958	335,177
Crop inventories	157,694	3,720	6,550	337,484	103,416	85,590	12,649
Total capital	5,147,961	1,033,318	655,607	12,022,553	3,013,393	4,611,684	1,349,121
				Percent			
Return to capital	5.87	6.70	11.78	6.71	16.76	7.75	9.22
				1,000 dollars			
1982:							
Land and structure	2,501,003	532,191	328,169	6,992,821	1,955,601	2,148,060	825,681
Machinery and equipment	492,184	145,474	30,368	2,006,194	187,908	750,964	118,666
Livestock inventories	941,982	273,006	274,470	2,551,538	1,347,751	1,233,106	435,793
Crop inventories	157,293	1,187	278	265,660	12,790	61,946	33,986
Total capital	4,092,462	951,858	633,285	11,816,213	3,504,050	4,194,076	1,414,126
				Percent			
Return to capital	9.86	10.48	18.28	8.37	20.82	10.80	11.68

average milk prices for the seven States because of local marketing order prices. In contrast, California received a far lower average price for milk, suggesting that marginal productivity and, therefore, the efficiency of its capital are considerably higher than in the northern and Lake States.[5]

Separating the influence of dairy-support programs from returns earned under a strictly market-oriented environment would be helpful in assessing differences in regional returns. Dairy programs simultaneously affect relative prices and production, and they partially explain the differential returns; however, we do not disentangle these effects here.

The variation among States in the average of the ratio of capital services to output for both years, which measures capital intensity, shows the differences in relative factor usage among regions. The ratio is larger in California (0.82), Florida (0.74), and Texas (0.77), relative to all States where values averaged 0.63. Although the ratio of capital to output is highest in the southern and western States, their rates of return to capital imply underinvestment in capital, which suggests these States should invest in more capital, making them considerably more capital-intensive relative to the other States.

Productivity Estimates

Productivity estimates are made from two perspectives: time (a comparison between 1978 and 1982) and region (a bilateral comparison of productivity between one arbitrarily chosen State, Pennsylvania, and the other States). Measuring the growth in TFP for different regions will enable us to compare relative efficiencies among regions. That is, after controlling for differences in input levels among regions, we can determine how much more output one region can produce than another for a given set of inputs.

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[5] One reviewer pointed out that the difference in nondairy outputs across States appears to make total outputs noncomparable. Although weighting the various outputs by their relative contribution to total revenue would allow for aggregation, we see, upon close inspection, that individual nondairy outputs constitute less than 1 percent of output; in fact, the total of all nondairy components of output represents only a little over 10 percent. This comparison demonstrates the advantage of using SIC classifications because the primary output is the one defined by the classification. To examine whether the interstate price differential has a significant effect on TFP, we looked at the average price received for milk in each State for 1978 and 1982. We compared each State's price with the seven-State average. We discovered Florida's price was approximately two standard deviations above the mean, whereas California's was one standard deviation below. All other States were very close to the mean. Florida was biased upward, but California was biased downward.

Because this is an industry study, output is measured gross of intermediate products rather than value added. Christensen (*2*) points out that, although aggregate productivity studies use value added because intermediate products are canceled out across sectors (that is, one sector's output is another sector's input), intermediate products do not cancel at the sector or industry level.

We assume the dairy sector is characterized by constant returns to scale (CRS), which implies that the necessary condition for producer equilibrium is that the shares of intermediate inputs and value added to total gross product sum to unity (*10*). Assuming away increasing (decreasing) returns to scale may yield a positive (negative) bias in the TFP estimates (*4*). We maintain CRS because that assumption is implicit in the data construction and, unless we econometrically estimate a dairy production function, we do not know the degree of returns to scale.

The input categories consist of capital services (K), labor (L), and materials (M). One calculates capital services by weighting capital stocks by the rate of return to capital.[6] Labor is defined as the value of hired labor compensation plus self-employed and unpaid family labor valued at the hired wage rate. Material inputs include all intermediate purchased inputs and services such as feed, seed, energy, agricultural chemicals, and veterinary services. Assuming CRS and perfect competition in factor markets implies that we can define factor cost shares as input weights equivalent to output elasticities. With these assumptions, we can aggregate total input using a Tornqvist approximation to the Divisia index (*5*). Aggregating all factors with a Divisia index procedure permits us to estimate TFP growth that is not biased by the lack of factor substitution possibilities implied by average product productivity measures (for example, a Laspeyres index of TFP). The index is written as:

$$\ln(X_T/X_O) = 1/2 \sum_i (S_{iT} + S_{iO}) \ln(X_{iT}/X_{iO}) \qquad (1)$$

where X is total input in period T and the base period O, and S is the cost share of input X_i. Total output, input, and average factor shares appear in table 4.

All factor shares tended to be comparable across most States. The share of labor was fairly constant at about 9-15 percent. Materials were most important in 1978 at 50 percent or more for all States and then declined to 40-45 percent in 1982. Capital varied within a range of 33-40 percent in 1978 and rose to 44 percent in 1982. Capital's share increased in the latter period, decreasing the shares of the other two inputs. This rise in capital's share was largely a function of the general increase in the calculated rate of return to capital.

The TFP index procedure also uses the Tornqvist index. This procedure allows us to define growth in TFP as growth in output minus the factor share-weighted growth in inputs. Because the growth rates are calculated as natural logarithms, by taking the exponential of the growth rates, we can convert them to index levels, which results in the base period being equal to 1. To compare the productivity level across States, we use a method of bilateral comparison (*3*). The productivity level of one State is selected as the base (that is, equal to 100), and each State is individually compared with it in both periods. Both intertemporal and interspatial indexes are produced by use of the Tornqvist index. The Tornqvist index for TFP growth is written as;

$$\ln(TFP_T/TFP_O) = \ln(Y_T/Y_O) - 1/2 \sum_i (S_{iT} + S_{iO}) \ln(X_{iT}/X_{iO}) \qquad (2)$$

where Y is output, and the other variables are as in equation 1. The time subscripts can be replaced with subscripts denoting regions. This substitution provides a measure of productivity differentials across regions. The intertemporal and interspatial levels of productivity appear in table 5. If 1978 = 100, the average annual TFP growth rate for the seven States was 2.5 percent. This growth rate is considerably less than the 11-percent annual growth in output per labor hour since 1979 reported by Fallert and others (*7*). Their study suggests the reasons for the rather large increase in productivity were the loss of some less efficient farms, substantial increases in capital, and improved breeding, feeding, and management. Our results (which are

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[6] It is interesting to note the possible effects of increases in capital consumption allowances (CCA) and indirect business taxes (IBT) on capital services and subsequently on TFP. Because one derives capital income by subtracting labor compensation, CCA, and IBT, an increase in CCA or IBT will reduce the rate of return to capital. That process will then decrease the value of capital services according to our method and thereby increase TFP.

Table 4—Constant 1977 dollar value of output, input, and factor shares, 1978 and 1982

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				1,000 dollars			
1978:							
Output	501,953	120,620	109,261	1,354,613	635,133	604,569	174,561
Capital	314,126	72,573	78,312	833,871	508,336	372,795	131,650
Total labor	106,134	29,017	27,031	258,675	103,275	132,745	36,977
Materials	359,503	114,303	134,237	801,148	601,906	504,161	200,936
Sum of share-weighted inputs	306,737	88,813	103,861	741,457	520,275	406,829	159,849
				Percent			
Capital share	40.3	33.6	32.7	44.0	41.9	36.9	35.6
Labor share	13.6	13.4	11.3	13.7	8.5	13.1	10.0
Materials share	46.1	52.9	56.0	42.3	49.6	49.9	54.4
				1,000 dollars			
1982:							
Output	598,683	151,783	150,727	1,571,435	879,514	704,535	216,506
Capital	413,626	102,229	116,544	1,012,770	732,457	464,567	170,584
Total labor	121,922	35,144	29,278	328,403	120,614	164,003	38,075
Materials	337,544	105,153	120,342	904,360	646,400	475,021	182,899
Sum of share-weighted inputs	343,477	93,776	108,662	869,022	646,144	424,400	163,451
				Percent			
Capital share	47.4	42.2	43.8	45.1	48.8	42.1	43.6
Labor share	14.0	14.5	11.0	14.6	8.0	14.9	9.7
Materials share	38.7	43.4	45.2	40.3	43.1	43.0	46.7

Table 5—Total factor productivity, intertemporal and interspatial comparisons, 1978 and 1982

State	Intertemporal		Interspatial	
	1978	1982	1978	1982
	Percent			
	— 1978 = 100 —		Pennsylvania = 100	
Pennsylvania	100.0	106.5	100.0	100.0
Vermont	100.0	112.0	86.8	91.3
Florida	100.0	124.1	70.9	82.6
Wisconsin	100.0	97.8	111.1	102.1
California	100.0	112.1	81.4	85.7
New York	100.0	106.6	93.0	93.1
Texas	100.0	117.0	73.4	80.7

consistent with those suggestions) illustrate that, when output is compared with the total measure of input, the productivity measure is often considerably less than the partial measure. Nonetheless, there are other significant influences (such as loss of farms and management) that are difficult, if not impossible, to measure and that are important to the productivity result.

Florida had the highest annual average rate of growth in productivity, 5.4 percent. Texas, California, and Vermont had annual growth rates of 3.9, 2.8, and 2.8 percent, respectively. New York, Pennsylvania, and Wisconsin had lower growth rates of 1.6, 1.58, and −0.55 percent per year, respectively. Except for Vermont, the traditional dairy States—especially Wisconsin—had TFP growth rates below the mean. Florida, Texas, and California had above-average TFP growth rates.

The higher TFP rates of the southern and western States may be a result of their relative capital intensity; that is, capital may contribute more to output than the other inputs do. If one region has more capital relative to labor or materials (for example, larger herds), this does not necessarily mean that other regions have different technologies. It does imply that they face different relative input price ratios and, therefore, have a different mix of inputs; that is, these regions are at different points along an isoquant. However, Florida and Texas have newer enterprises; therefore, they may have an advantage of operating with new capital equipment having technological improvements. The northern States generally have traditional dairy farms with older types of capital technology with fewer technological improvements than the southern and western States. These two regions may not share the same type of capital and, thus, may not be directly comparable.

Comparing bilateral productivity highlights spatial differences. If Pennsylvania's level of productivity is set to equal 100, Wisconsin was more efficient than Pennsylvania; however, New York and Vermont were less efficient than Pennsylvania in 1978, but increased somewhat in 1982. California, Florida, and Texas were less efficient than Pennsylvania in both 1978 and 1982. These comparisons are bilateral, not multilateral; therefore, we cannot compare TFP among States, but only individually with Pennsylvania. Nonetheless, productivity differs somewhat between the northern and southern regions. Finally, the important distinction between the intertemporal and interspatial productivity comparisons is interesting. Although the rate of growth in TFP over time is generally higher in the southern States, it does not mean that at a given time these States are the most efficient producers. However, according to TFP growth rates, they have certainly improved.

One advantage of having both intertemporal and interspatial TFP estimates is that the combination illustrates regional comparative advantage. For example, given their relative TFP levels in 1982, Wisconsin and Pennsylvania could probably survive an unexpected increase in production costs better than Florida or Texas could. The northern States appear to have this advantage because Wisconsin and Pennsylvania produce more output for a given level of input than the southern States. However, if we can extrapolate 1982 TFP growth rates into the future, the southern States will probably be more efficient and have a comparative advantage later. For example, let us compare Florida and Pennsylvania. In 1982, Florida had a TFP level of 82.5 and a growth rate of 5.4 percent, compared with Pennsylvania's TFP level of 100 and growth rate of 1.6 percent. Using a compound growth rate formula, we find Florida will exceed Pennsylvania's TFP level in just 3 years. Of course, this projection assumes current production practices remain the same across regions.

A policy change like the Dairy Herd Buy-Out provision of the 1985 farm act could significantly change regional productivity. This provision reduces milk production by 12 billion pounds from April 1986 to August 1987. To do so, the Government will buy out whole dairy herds and not permit other farmers to use the associated dairy facilities. Although using 1982 regional TFP estimates to examine events in 1986 may be inappropriate, participation rates in the buy-out program are highest in the regions where estimated TFP levels are lowest. This finding is not surprising since one would expect marginal producers to leave the sector first. Differing opportunity costs associated with staying in production also explain differential participation. For example, some of the reasons given for the exit of marginal producers are low returns, financial problems, and attractive alternatives. Lower participation rates in the northern States result from fewer alternatives for these producers or for their land and equipment. The higher TFP *growth* rates in the southern and western States suggest they had become more productive. If they are financially stressed now and see this program as an opportunity to liquidate, the buy-out program may encourage the potentially most productive producers to move out of the sector, which will probably affect the milk price structure. Therefore, although the program may have little impact on northern producers, the potentially more productive dairy farms in the South and West may produce less milk, altering regional productivity differentials.

Sources of Growth

After determining a measure of aggregate TFP, we investigated the extent to which growth in output is a result of either productivity gains or growth in various factor inputs. We can thus clarify the relationship between technological change and structure (where structure is defined as the relationship between, and the growth of, inputs).

Utilizing the relationship that growth in output should equal the weighted-average growth in inputs, we can determine the sources of growth in output (*13*). Assuming an aggregate production function for dairy, we can express the rate of change in output as:[7]

$$\hat{Y} = w_k\hat{K} + w_l\hat{L} + w_m\hat{M} + \hat{A} \tag{3}$$

where ∧ denotes proportionate rates of change and w_i are the factor share weights of total output. The share-weighted growth of an individual input indicates the contributions of that input to output growth. We can also express the growth rate of inputs and productivity as a percentage of the growth of output. This procedure suggests which portion of the growth in output can be attributed to specific inputs or to productivity. For example, the growth of output in New York was almost twice the growth in inputs, implying that input growth accounts for roughly half the growth in output. The residual, or $\hat{A}$ from equation 3, is the portion of output growth not explicitly explained by input growth; it is attributed to productivity growth.[8]

The contribution of total input growth to output varied considerably for all States (table 6). In California, input growth accounted for as much as 65 percent of output growth; in Texas and Florida, input growth acccounted for only 27 and 33 percent,

Table 6—Sources of growth, 1978-82

Item	Pennsylvania	Vermont	Florida	Wisconsin	California	New York	Texas
				Percent			
Average annual growth rates:							
Output	4.41	5.75	8.04	3.71	8.14	3.83	5.38
Total input	2.83	2.91	2.64	4.26	5.29	2.22	1.45
Capital	3.02	3.24	3.80	2.17	4.14	2.17	2.56
Labor	.48	.67	.22	.84	.32	.74	.07
Materials	−.67	−1.00	−1.38	1.25	.83	−.69	−1.19
Total factor productivity (TFP)	1.58	2.84	5.40	−.55	2.85	1.60	3.93
Growth in inputs and TFP:[1]							
Total input	64.13	50.64	32.82	114.78	65.01	58.09	26.92
Capital	68.44	56.48	47.25	58.34	50.91	56.82	47.66
Labor	10.85	11.64	2.76	22.73	3.95	19.35	1.34
Materials	−15.16	−17.48	−17.19	33.70	10.16	−18.09	−22.08
TFP	35.87	49.36	67.18	−14.78	34.99	41.91	73.08

[1] As a percentage of the growth of output.

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[7] As indicated in footnote 2, we really assume a multiple-output production function. For simplicity in the growth-accounting procedure, we assume outputs to be aggregated as a single index. The derivative of the share-weighted growth in output follows Denny, Fuss, and Waverman (*4*) and Solow (*13*). We can express the production function as:

$$y = f(x_i, t) \tag{A.1}$$

where t represents time. Totally differentiating equation A.1 with respect to time and dividing by y yields:

$$(dy/dt)(1/y) = \sum_i (df/dx_i)(dx_i/dt)(1/y) + (df/dt)(1/y) \tag{A.2}$$

Define the last term on the RHS as a Hicks' neutral proportionate shift in the production function, and denote it as $\hat{A}$. Multiplying the second term by x_i/x_i produces the x_i output elasticities. Assuming competitive markets, the output elasticities will equal factor shares of output. Therefore we can express equation A.2 as:

$$\hat{Y} = \sum_i w_i\hat{X}_i + \hat{A} \tag{A.3}$$

[8] The residual is an unknown. It could contain such elements as effects of changing input quality, changes in capacity utilization, economies of scale, or management and entrepreneurial capacity. Given the size of the residual and the number of possibilities that may explain it, it has also been called a "measure of our ignorance" (*1*).

respectively. The growth in inputs in Wisconsin was so great relative to output that inputs had negative growth in TFP. Capital was a major contributor to input growth in all States. The largest increases were in California and Florida, probably a result of large calculated returns to capital. To determine if these rates of return alone accounted for capital's significant role, we calculated capital services with both a lower rate of return and the same rate for all States. In both cases, the role of capital was significant.

The contribution of labor to output growth in the northern dairy States exceeded that in the southern and western States. Although operator labor may be undervalued when the hired wage rate is used, technology in the South and West is far more capital intensive than in the North. The relatively high capital growth rates in Florida and California are also consistent with the high relative rates of return to capital that attract capital investment. Furthermore, the northern and eastern States are characterized by smaller and more numerous farms with more operators and, hence, are more labor intensive relative to output.

The role of materials is problematic. The real quantity of material inputs may have declined in the 1978-82 period. However, it is more likely that the effective quantity or quality-adjusted quantity increased. This increase was probably due to the index number problem; that is, either inappropriate deflators were used for inputs (and outputs) or quantity weights in the indexes were not quality-adjusted and, therefore, do not reflect their true productive capacity. For example, greater use of improved feed additives and improved breeding practices and veterinary services would have increased the productive capacity of these purchased inputs. The role of materials appears most important in Wisconsin and less important in California. One possible explanation is that feed is generally purchased in California, whereas it is grown on farms in Wisconsin and other northern States, thereby requiring farmers to purchase seeds, fertilizers, and other material inputs.

TFP was the major source of output growth in all States except Wisconsin. Texas and Florida received the largest contributions from TFP because of declines in material inputs relative to a positive growth in output. One should remember that TFP is a residual measure; that is, the residual captures the productive qualities that do exist and are not accounted for by the input measurements. Accurate input measurement thus requires that all inputs be measured in efficiency units. Because of the new technologies, improved breeds and the use of feed additives, the contribution of both capital and the material input may be underestimated.

Conclusions

We have demonstrated a method to determine the differences in TFP within an industry and at the regional level. We developed constant dollar income and product accounts for the three-digit SIC dairy sector for Pennsylvania, Wisconsin, New York, Vermont, California, Florida, and Texas. We showed the importance and usefulness of income and product accounts as an economic tool by examining several variables: gross dairy product (valued-added output), profit income (net farm income), property compensation, and the rate of return to capital. The southern and western States had higher rates of return to capital than the northern States. The average TFP growth for the seven States from 1978 to 1982 was estimated at 2.5 percent per year, considerably lower than previous estimates of output per labor hour for the entire dairy sector. TFP estimates indicate that the southern States generally had higher TFP growth rates than the northern dairy States.

Bilateral interspatial TFP estimates were made for 1978 and 1982. Although the southern and western States had higher TFP growth rates over time, the northern States were generally more efficient in both periods. It is important to distinguish the two types of productivity. Capital was an important source of output growth in all regions, and materials were less important. The contribution of labor was more important in the more traditional regions and less important in the more capital-intensive regions. Productivity growth was significant in all regions.

These findings suggest two things. First, structure (in terms of relative factor intensity and growth) is important in explaining output growth and productivity differences across regions. Second, TFP growth and technological change are important contributors to regional output growth differentials. TFP is a residual based on measured items that can have measurement error; therefore, part of the residual is TFP, and part is measurement error. Nonetheless, the basic income accounting procedure is useful. When properly used, it can identify and examine the sources of growth and productivity of different regions.

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Appendix table—Deflator sources

Item	Source/price index	Deflators	
		1978	1982
		1977 = 100	
Crop cash receipts:			
Grain	Food grains	122	146
Cotton and cottonseed	Cotton	91	92
Tobacco	Tobacco	109	153
Field seeds, hay, forage, and silage	Feed grains and hay	101	120
Vegetables, sweet corn, and melons	Commercial vegetables	105	126
Fruits, nuts, and berries	Fruit	137	175
Nursery and greenhouse products	All crops	105	121
Other crops	do.	105	121
Livestock cash receipts:			
Poultry and products	Poultry and eggs	106	110
Dairy products	Dairy products	109	140
Cattle and calves	Meat animals	134	155
Hogs and pigs	do.	134	155
Sheep, lambs, and wool	do.	134	155
Other livestock	Livestock and products	124	145
Government payments	All farm products	115	133
Custom work	Farm services and cash rent	107	145
Rents	do.	107	145
Recreational services	Consumer price index, all items (*6*)	107	172
Other income:			
Home consumption	All farm products	115	133
Change in inventories:			
Crops	All crops	105	121
Livestock	Livestock and products	124	145
Intermediate products	Production items	108	155
Custom work expense	Farm services and cash rent	107	145
Rent expense	do.	107	145
Labor compensation	Wage rates	107	144
Repairs	Production items	108	155
Other expenses	do.	108	155
Capital consumption	Farm producer durable equipment (*19*)	108	148
Property taxes	Taxes	100	124
Net interest	Interest	117	241
Capital stocks:			
Land and structure	Real estate values (*15*)	109	157
Machinery and equipment	Farm producer durable equipment (*19*)	109	165
Livestock inventories	Livestock and products	124	145
Crop inventories	All crops	105	121

Source: All items from (*18*), except where noted.

Forecasting Performance of Models Using the Box-Cox Transformation

David M. Smallwood and James R. Blaylock

Abstract

The authors examine the small sample properties and forecasting performance of estimators in models using the Box-Cox transformation via a Monte Carlo experiment. They develop a simple estimator for the expected value of the untransformed dependent variable. They show that the sign and magnitude of the transformation parameter influence the precision of the estimators and the forecasting performance. These results support previous research. At different values of the transformation parameter, smaller variances of the parameter estimators do not necessarily imply improved goodness of fit for the model.

Keywords

Forecasting performance, transformations, Box-Cox, flexible functional forms

Economic theory usually provides few details as to the specific functional relationships among variables in econometric models. Therefore, the applied research economist is often forced to choose among many competing functional forms using noneconomic criteria. Flexible functional forms, because they minimize this subjective aspect of model construction, are becoming increasingly popular as a tool to discriminate among competing models' specifications. One frequent approach for adding flexibility to models is to incorporate the monotonic transformation introduced by Box and Cox (*3*).[1] Models incorporating the Box-Cox transformation allow researchers to discriminate statistically among many commonly used functional forms including the log, inverse, quadratic, and linear forms (*1, 4, 6, 8, 12, 14*). However, the Box-Cox transformation places additional burdens on the researcher in terms of the complexity of estimating and interpreting model parameters compared with ordinary-least-squares models. Furthermore, the small sample properties of the estimators and the forecast performance of models incorporating a transformed dependent variable are not well known (*11*).

Several papers have addressed estimation procedures and interpretation of parameters in Box-Cox models, but only Spitzer (so far as we know) has addressed the small sample properties and forecast performance. Estimating parameters in models employing the Box-Cox transformation involves maximizing a complex nonlinear likelihood function. Spitzer has outlined several procedures that can be used to accomplish this task (*12*). Procedures for interpreting parameters in Box-Cox models are discussed by Spitzer (*12*), Blaylock and Smallwood (*1, 2*), and others.

The small sample properties of the estimators are particularly important for the applied researcher. For example, how well do the estimators perform when one has only 30, or perhaps 60, observations? Can one use the standard t-test to test hypotheses about the model parameters? Although the maximum likelihood properties are well known, they apply only asymptotically, and the small sample properties are analytically intractable.

Spitzer has investigated the small sample properties of the Box-Cox estimators via Monte Carlo methods (*11*). However, as he notes, his results are tempered by the small number of replications (50) per model. Furthermore, he touches on forecast per-

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[1] Italicized numbers in parentheses refer to items in References at the end of this article.

formance only as a secondary issue.[2] Thus, several important questions, such as the calculation of the expected value of the untransformed dependent variable and out-of-sample forecast performance, are not addressed.

This article has two major objectives. Our first objective is to expand Spitzer's Monte Carlo study (*11*) by using twice the number of replications to provide more reliable information on the small sample properties of estimators in Box-Cox type models. The small sample properties of estimators have important implications for economists, and the properties of these estimators ultimately extend to the end use of the model. For example, consider the importance of a parameter's variance. Spitzer has suggested that, in highly nonlinear functional specifications such as the Box-Cox, the sign and magnitude of the transformation parameters may affect the estimation of the variances for all parameters in the model. If so, one must exercise extreme care in performing hypothesis tests, especially if the tests imply or embody policy or program implications.

Our second objective is to investigate the ability of transformed models to forecast the original (untransformed) variable and to forecast outside the sample used for estimation. Forecast performance is important in evaluating flexible functional forms because a common fear is that they fit an individual sample too well, including the random peculiarities. Limited numbers of observations in analyses of live data often prevent extensive testing outside the period of fit. Monte Carlo studies, in contrast, provide a unique opportunity for testing this aspect of model performance. The evaluation of forecasting performance in a scientifically controlled environment using simulated data provides the applied economist with valuable insights into the strengths and limitations of the Box-Cox technique.

To accomplish these objectives, we conducted a Monte Carlo experiment using the general framework set forth by Spitzer (*11*). The general model consisted of three variables and five parameters including a single Box-Cox parameter. The model was used to generate some 100 samples of observations which were used for estimation and forecast evaluation. This was done for five alternative Box-Cox parameter values and for two sample sizes. In contrast to Spitzer (*11*), each data sample contained 10 observations for use in forecast evaluation that were not used to estimate the model parameters.

We discuss the Box-Cox transformation and the method of estimation, and we outline model construction and data generation. We then discuss estimation and forecasting performance results and briefly summarize our research findings.

Box-Cox Transformations

The Box-Cox transformation for any positive variable W is defined as:

$$\begin{aligned} W(\lambda) &= (W^{\lambda} - 1)/\lambda. \qquad \lambda \neq 0 \\ &= \ln(W), \qquad \lambda = 0 \end{aligned} \tag{1}$$

where λ is a parameter to be estimated. The transformation is typically applied to models of the form;

$$Y_i(\lambda) = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) + \epsilon_i, \; i = 1, 2, \ldots, N \tag{2}$$

The linear and logarithmic models are special cases of equation 2 when λ is equal to 1 and zero, respectively (*14*).

Assume that under the appropriate transformation, the ϵ_i' s are independently and normally distributed with zero mean and constant variance, that is, $N(0, \sigma^2)$. The likelihood function can then be written as:

$$\begin{aligned} L(\beta, \sigma, \lambda) = (2\pi\sigma^2)^{-N/2} J \exp \Big[- \sum_{i=1}^{N} \Big\{ Y_i(\lambda) - \beta_0 \\ - \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) \Big\}^2 / 2\sigma^2 \Big] \end{aligned} \tag{3}$$

where J denotes the Jacobian for the transformation from $Y_i(\lambda)$ to the observed Y_i:

$$J = \prod_{i=1}^{N} \left| \partial Y(\lambda) / \partial Y \right| = \prod_{i=1}^{N} Y_i^{\lambda - 1} \tag{4}$$

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[2] Spitzer's method (*11*) of deriving forecasts is shown in this article to be incorrect.

The log-likelihood function can be written as:

$$LL = -(N/2)\ln \tilde{\sigma}^2 + (\lambda - 1) \sum_{i=1}^{N} \ln(Y_i) \qquad (5)$$

where $\tilde{\sigma}^2 = \sum_{i=1}^{N} \tilde{\epsilon}_i^2 / N$ is the estimated variance of ϵ_i.

We used the Fletcher-Powell algorithm with analytically computed first derivatives to maximize the log-likelihood function.[3] We used the fundamental statistical relationship that the asymptotic covariance matrix of a maximum likelihood estimator is equal to the inverse of the covariance matrix of the gradient of the likelihood function when estimating the asymptotic covariance matrix of the parameters (*10*).

Zarembka has shown that the distribution of the error term cannot be strictly normal in models where the dependent variable is Box-Cox transformed because a power transformation can be applied only to positive variables (*14*).

Specifically, if $\lambda > 0$, then $-1/\lambda < Y(\lambda) < \infty$; if $\lambda = 0$, then $-\infty < Y(\lambda) < \infty$; and if $\lambda < 0$, then $-\infty < Y(\lambda) < -1/\lambda$. Consequently, the magnitude and sign of λ affect the range of the dependent variable. However, Draper and Cox (*5*), Zarembka (*14*), and Spitzer (*12*) have shown empirically that so long as the distribution of the error term is reasonably symmetric and the probability of large negative values of the error term is low, normality may be a good approximation.

Model Construction and Data Generation

Following Spitzer (*11*), we specified the models as:

$$Y(\lambda) = 9.0 - 1.5X_1(\lambda) + 0.5X_2(\lambda) + \epsilon \qquad (6)$$

where $\lambda = -1.5, -1.0, -0.15, 1.0, 1.5$, respectively, for the five models. These values of λ were selected to represent a large range of possible transformation parameters because the size and sign of the parameter may be important in determining the shape and location of the sampling distribution of the coefficient estimates and may affect the forecasting ability of the models. In addition, the $X_i(\lambda)$'s were constructed such that:

$$\beta_1^2 \operatorname{var}(X_1(\lambda)) = \beta_2^2 \operatorname{var}(X_2(\lambda))$$

This condition was set so that each variable has equal importance in explaining the variance of $Y(\lambda)$.

The method used to generate values of $X_1(\lambda)$ and $X_2(\lambda)$ appears in the appendix. All models were estimated for 100 samples of sizes 30 and 60 ($N = 30, 60$). An additional 10 observations were also generated for each sample for use in evaluating the out-of-sample forecasting performance. The equation error term was generated from a population that was independently distributed as $N(0, \sigma^2)$, where $\sigma^2 = 0.4263$. The value of σ^2 was chosen to yield a residual variation equal to 5 percent of the total variation in $Y(\lambda)$.

Tukey (*13*) and Box and Cox (*3*) argue that the purpose of a transformation is to increase the degree of approximation to which three desirable properties for statistical analysis hold. In particular, they argue that transformations may lead to a more nearly linear model, may stabilize the error variance, and/or may lead to a model for which a normally distributed error term is acceptable. Of course, a transformation may increase the degree of approximation to two or more of these properties simultaneously. The true models are constructed such that all three properties hold simultaneously. The estimated models should, therefore, seek out the transformation parameter that stabilizes the error variance and normalizes the error distribution.

The calculation of unbiased predicted values in transformed models requires that special attention be given to the error term. Transformed dependent variables make predictions more difficult because one is interested in predicting the expected value of the original (untransformed) dependent variable rather than the transformed one. One derives the simplest predictor of Y_i, and probably the predictor most often used, by first noting that:

$$E\left[Y_i(\lambda)\right] = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) \qquad (7)$$

---

[3] Spitzer used a modified Newton technique for estimation (*11*).

and then solving for Y_i:

$$Y_i = \left[1 + \lambda\left[\beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda)\right]\right]^{1/\lambda}, \quad \lambda \neq 0$$

$$= \exp\{\beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda)\} \qquad , \lambda \to 0 \qquad (8)$$

However, the expressions in equation (8) are equal to the expected value of Y_i only in the case of the linear model. For $\lambda \neq 1$, the expressions are biased estimators.[4] These formulas are biased because the expected value of a nonlinear function is not equal to the nonlinear inverse function of the expected value (7). In other words, the error term cannot be dropped from equation (7) before expectations are taken.

A simple approximation to the expected value of the original (untransformed) dependent variable can be derived as follows. First, define the model in terms of the transformed dependent variable as:

$$Z_i = (Y_i^\lambda - 1)/\lambda = \beta_0 + \sum_{k=1}^{K} \beta_k X_{ik}(\lambda) + \epsilon_i \qquad (9)$$

and note that the original dependent variable can be expressed as:

$$Y_i = F(Z_i) = (\lambda Z_i + 1)^{1/\lambda} \qquad (10)$$

where $F(Z_i)$ denotes the inverse of the Box-Cox transformation.

Expressing Y_i as a second-order Taylor expansion around the expected value of the transformed dependent variable yields:

$$Y_i \approx F(\tilde{Z}_i) + (Z_i - \tilde{Z}_i)(\lambda\tilde{Z}_i + 1)^{(1-\lambda)/\lambda} + \tfrac{1}{2}(Z_i - \tilde{Z}_i)^2(1-\lambda)(\lambda\tilde{Z}_i + 1)^{(1-\lambda)/\lambda} \qquad (11)$$

where $\tilde{Z}_i = E(Z_i)$. One derives the expected value of the expression in equation (11):

$$E(Y_i) \approx F(\tilde{Z}_i) + \tfrac{1}{2}\sigma^2(1-\lambda)[F(\tilde{Z}_i)]^{1-2\lambda} \qquad (12)$$

by noting that the second term on the right-hand side (RHS) of equation 11 vanishes, that the expected value of $E(Z_t - \tilde{Z}_t)^2$ is the equation error variance, and that:

$$[(\lambda\tilde{Z}_i + 1)^{(1-2\lambda/\lambda)}] = [(\lambda\tilde{Z}_i + 1)^{1/\lambda} \bullet (\lambda\tilde{Z}_i + 1)^{-2}]$$

$$= [F(\tilde{Z}_i)]^{1-2\lambda} \qquad (13)$$

The expression given in equation 12 differs from the simple formula of equation 8 by the second term on the RHS of equation 12. The sign of this term, which is uniquely determined by the value of λ, indicates the direction of bias involved by using equation 8 in lieu of the formula given in equation 12. A negative bias is generally present if $\lambda < 1$, and a positive bias is present if $\lambda > 1$.

We examine the small sample performance of the model parameters using a variety of performance statistics to measure bias and variation. For each parameter estimated in equation (6), let $\tilde{\theta}_i$ be the i-th sample value of the parameter, let $\sigma(\theta_i)$ be the asymptotic standard deviation of θ_i, and define the following:

Mean bias = $\sum \tilde{\theta}_i/N - \theta$,

Mean absolute bias = $\sum |\tilde{\theta}_i - \theta| /N$,

Root mean square error = $[\sum (\tilde{\theta}_i - \theta)^2/N]^{1/2}$, and

Mean asymptotic standard deviation = $\sum \sigma(\tilde{\theta}_i)/N$.

We use these statistics to evaluate the forecasting performance of the various models by assuming that $\tilde{\theta}$ represents the forecast value and θ represents the true value of the observation to be predicted.

Estimation and Forecast Performance

Table 1 shows mean bias (MB) and mean absolute bias (MAB) statistics for the coefficient estimates of the alternative simulations. The most striking result is perhaps the remarkable similarity between our results and those of Spitzer (*11*). Like Spitzer, we find that, except for β_0 in models with $\lambda > 0$, the MB's are relatively small and do not appear to indicate systematic under- or overestimation of para-

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[4] Elasticity formulas frequently employed in studies using the transformation-of-variables technique are also in error because they are based on the same erroneous assumption about the expected value of the dependent variable.

Table 1—Mean bias (MB) and mean absolute bias (MAB) of parameter estimates

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$	$\frac{MAB(\lambda)}{\lambda}$
	Sample size	*Estimates*				
MB:						
−1.5	30	−0.057	0.024	0.042	0.046	NA
	60	−.245	.012	.035	.044	NA
−1.0	30	−.085	.009	.040	.025	NA
	60	−.095	.016	.020	.017	NA
−0.15	30	−.021	−.014	.025	−001.	NA
	60	−.118	−.013	.016	−.000	NA
1.0	30	3.667	−.154	.003	−.017	NA
	60	2.026	−.117	−.005	.020	NA
1.5	30	4.394	−.156	.002	.027	NA
	60	2.302	−.116	−.006	.030	NA
MAB:						
−1.5	30	.952	.061	.092	.124	0.083
	60	.782	.045	.075	.102	.068
−1.0	30	.914	.064	.106	.098	.068
	60	.650	.042	.067	.065	.065
−0.15	30	1.538	.075	.137	.029	.193
	60	1.187	.046	.100	.020	.133
1.0	30	7.071	.521	.079	.233	.233
	60	4.203	.345	.045	.146	.146
1.5	30	7.884	.517	.076	.334	.223
	60	4.575	.342	.043	.210	.140

NA =Not applicable.

meters. However, the MAB's for β_0 and β_1 in models with positive λ's are several times larger than their counterparts in models with negative λ's. The MAB's for all model parameter estimates decline with increased sample size. Coupled with similar findings by Spitzer, this decline indicates the estimates are consistent. The MAB of λ as a percentage of λ generally increases as λ increases, indicating that the variance of λ increases as λ increases. Spitzer also noted this phenomenon. Therefore, the problem seems not to be one of a small number of sample replications.

The MB and MAB statistics show that: (1) parameter estimates are unbiased and consistent; (2) models with positive λ's perform less well than other models in terms of MB and MAB statistics; (3) the variance of λ seems to increase as λ increases; and (4) our results are similar to those of Spitzer, which is comforting in terms of the reliability of the test statistics and because we obtained our results using different estimation techniques.

Table 2 presents the root mean square error (RMSE) and mean asymptotic standard deviation (MASD) statistics for the parameter estimates. If parameter estimation bias is small, the MASD's should be good approximations to the RMSE's (that is, the ratio of the MASD and RMSE for a parameter should approach 1 as sample size increases). The MASD's and RMSE's for all models decline as sample size increases, and their ratio is virtually equal to 1 for N = 60 in all cases. This finding suggests that the estimated variances are consistent. However, the statistics for positive λ are many times larger than those for the models with nega-

Table 2—Root mean square error (RMSE) and mean absolute standard deviation (MASD) of parameter estimates

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$
	Sample size	*Estimates*			
RMSE:					
−1.5	30	1.207	0.075	0.116	0.154
	60	.963	.055	.099	.130
−1.0	30	1.152	.080	.156	.129
	60	.810	.054	.088	.084
−0.15	30	1.978	.091	.177	.036
	60	1.531	.058	.132	.026
1.0	30	11.081	.693	.102	.301
	60	6.257	.467	.061	.191
1.5	30	12.805	.690	.098	.431
	60	6.952	.464	.059	.275
MASD:					
−1.5	30	1.640	.091	.171	.232
	60	1.037	.061	.102	.142
−1.0	30	1.397	.098	.182	.172
	60	.892	.061	.106	.104
−0.15	30	2.596	.100	.243	.049
	60	1.562	.061	.145	.029
1.0	30	13.378	.882	.119	.370
	60	6.387	.491	.066	.209
1.5	30	15.152	.870	.114	.530
	60	6.990	.485	.064	.300

tive λ, except for the statistics for β_2, which follow no obvious pattern. The results indicate that estimates from models with $\lambda < 0$ tend to be more precise.

One indicator of the concentration of the parameter estimates around the true parameter is the percentage of the estimates within ±20 percent of the true parameter (table 3). The results strongly indicate that models with a negative λ perform better. An examination of table 3 reveals that a larger percentage of the parameter estimates fall within the 20-percent range as λ decreases and as sample size increases. The exception is β_2, which shows no clear relationship with λ. However, as sample size increases, all parameters become more highly concentrated around the true parameter values. Thus, the parameter estimates obtained from larger samples and models with smaller λ are more precise than other models.

One must be cautious when using standard t-tests for hypothesis testing. To examine this issue further, we constructed two hypotheses. The first is a true hypothesis:

$$H_o : \beta_j = \beta_{jo},$$

where β_{jo} is the true value of β_j. Using a two-tailed test at the 0.05 significance level, we would expect to reject 5 percent of these hypotheses. Using the same procedures, we also tested the following false hypothesis:

$$H_o : \beta_j = 0$$

This test shows the power of the t-test (table 4).

The true hypothesis was rejected in 5 percent or less of the replications for models with a negative λ. The results were mixed for models with positive λ's,

Table 3—Percentage of estimates within 20 percent of true parameters

λ	N	$\tilde{\beta}_0$	$\tilde{\beta}_1$	$\tilde{\beta}_2$	$\tilde{\lambda}$
	Sample size	*Percent*			
−1.5	30	87	100	60	95
	60	95	100	74	97
−1.0	30	88	100	59	91
	60	98	100	79	96
−0.15	30	66	100	45	62
	60	77	100	65	73
1.0	30	22	37	70	54
	60	33	54	89	74
1.5	30	21	38	70	55
	60	32	56	89	75

Table 4—Rejections (R) and acceptances (A) of hypotheses[1]

λ	N	$\tilde{\beta}_0$		$\tilde{\beta}_1$		$\tilde{\beta}_2$		$\tilde{\lambda}$	
		R	A	R	A	R	A	R	A
	Sample size	*Numbers*							
−1.5	30	5	0	2	0	1	6	2	0
	60	5	0	5	0	3	0	5	0
−1.0	30	2	0	3	0	1	8	4	1
	60	5	0	4	0	2	0	2	0
−0.15	30	3	0	5	0	4	37	2	11
	60	5	0	4	0	5	0	4	0
1.0	30	9	100	6	54	1	1	3	24
	60	8	70	5	0	8	0	6	0
1.5	30	10	100	6	54	2	1	3	20
	60	8	81	5	0	9	0	6	0

[1] R denotes the number of samples out of 100 in which the true hypothesis $\beta_k = \beta_{k0}$ is rejected at the 0.05 level. A denotes the number of samples out of 100 in which the false hypothesis $\beta_k = 0$ is accepted as true.

although they are unambiguously worse than the statistics from the models with negative λ's.

Models with $\lambda < 0$ generally performed better than those with positive λ. For example, the false hypothesis, $\beta_0 = 0$, is never rejected for models with $\lambda = 1.0$, 1.5, and $N = 30$. In fact, even for the larger sample size ($N = 60$), a high percentage of the false hypotheses were accepted for the samples with $\lambda = 1.5$. However, the power of the test did tend to improve as sample size increased. The reason for the poor performance of the model with $\lambda > 0$ is, of course, the imprecision with which these model parameters are estimated. These test results are not encouraging for the application of t-tests to parameters estimated from Box-Cox models, especially for models with positive λ.

Table 5 reports test statistics for the equation error term. Contrary to Spitzer's assertion, our results

Table 5—Sample statistics for the error term, $\epsilon \sim N(0, 0.426)$

λ	N	MB of variance	MAB of variance	RMSE of variance	Percentage rejection of normality
	Sample size		*Estimates*		*Percent*
−1.5	30	−0.070	0.164	0.201	0
	60	−.058	.134	.164	3
−1.0	30	−.038	.170	.227	2
	60	−.028	.121	.144	0
−0.15	30	−.007	.138	.181	0
	60	−.013	.108	.133	0
1.0	30	1.413	1.653	4.394	35
	60	.474	.667	1.380	31
1.5	30	1.896	2.140	6.121	37
	60	.588	.787	1.541	34

Note: MB = mean bias, MAB = mean absolute bias, and RMSE = root mean square error.

clearly indicate that systematic bias occurs in the estimation of the error variance.[5] The models underestimate the true variance for λ less than zero, and they overestimate the variance for positive λ. This finding has serious implications for researchers because equation (12) expresses the expected value of the untransformed dependent variable as a function of the variance. Thus, forecasts made with equation (12) using an estimate of the variance will be biased, and the bias will depend on the size of the bias in the variance and the value of λ.

The MAB's and the RMSE's decline as sample size increases, indicating consistency. However, the test statistics for the models with a positive λ are many times larger than their counterparts derived from the models with a negative λ. In other words, the models with a positive λ once again performed far worse than their counterparts with a negative λ.

The error distribution cannot be strictly normal because of the limited range of the dependent variable. However, if the bounds implied on the error distribution occur in the extreme tails of the distribution as in the Monte Carlo experiment, departure from normality would not be expected to be significant. Table 5 shows the results of a test for normality of the estimated model error term using a two-tailed Kolmogorov-Smirnov goodness-of-fit at the 0.05 level. Regardless of sample size, normality was rejected in approximately one-third of the replications for models with positive λ. However, in the models with negative λ, normality was not rejected in the vast majority of cases.

Model performance is frequently evaluated in terms of its overall fit to the sample data. R^2, the coefficient of multiple determination, is probably the most often cited statistic for this purpose. When applying R^2 to models with a transformed dependent variable, one must be careful to compute it in terms of the original untransformed dependent variable because the untransformed dependent variable is the variable of interest and represents a standard for comparisons across models. Table 6 shows the average R^2's for the estimated models. The R^2's are higher for the extreme positive and negative values of λ than for $\lambda = -0.15$. When the R^2 criterion was used, models with $\lambda > 0$ performed the best of all models. R^2 decreased in larger size samples for $\lambda < 0$, but remained high and stable in models with positive λ. The drop in R^2 as sample size increases suggests that randomness in smaller samples may have more influence on the parameter estimates than in larger samples, resulting in a better fit to the particular sample, but not necessarily to the population of interest. This conjecture is consistent with the larger variances for the parameter estimates obtained in the smaller samples.

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[5] Except for $N = 30$ with $\lambda = -1.5$, Spitzer's reported results (*11*) indicate the same type of bias as we find. We believe that Spitzer may have been too generous in stating that no error variance estimation bias appeared in his replications.

Models with a positive λ again appeared to perform below those with a negative λ in terms of the parameter estimates, but the reverse was true for the overall fit to the untransformed data. We found a potentially serious problem in the form of a systematic bias in the model error variance for models with positive and negative values of λ.

Table 6 shows MB's, MAB's, and RMSE's for the forecasts. MB's and MAB's are small in all models examined, which suggests that the simulated Box-Cox models forecast reasonably well for both positive and negative λ. It is surprising that the largest MB's are in the linear model, λ = 1.0. The extreme nonlinear cases, λ = ±1.5, have the smallest MB's and MAB's. This finding contrasts markedly with the performance of the parameter estimators examined earlier in which performance declined as λ increased from negative to positive values, but it is consistent with the performance measured by R^2.

Forecasts, in contrast to parameter estimates, improve little as sample size is increased from 30 to 60 observations. This finding indicates a biased estimator. Inspection of the MB's reveals a clear pattern of bias in the forecasts. Models with negative λ exhibit a positive bias, while those with positive λ exhibit a negative bias.

The source of the forecast bias is not clear. It may arise from the Taylor series approximation used to compute the forecasts. However, recall that the parameter estimator for λ was biased upwards for all models, except for λ near zero, and that the model variance had a positive bias in models with a positive λ and a negative bias in models with a negative λ. Thus, because of the role played by these parameters in the forecast equation and because the expected value formula is only an approximation, a combination of factors may contribute to the forecast bias.

The RMSE and percentage error of the forecasts reveal that forecast performance improves as λ moves away from zero in either direction. Models with positive λ's appear to perform better than models with negative λ's, especially when measured relative to the mean values. Note that the linear model, λ = 1.0, performs quite well in terms of the percentage error criterion, whereas in terms of the MB it ranks much lower in performance. This situation is partially due to the mean forecast value, but the RMSE decreases markedly as λ increases.

Conclusions

We have investigated the small sample properties of estimators in Box-Cox type models and the out-of-sample forecast performance. We expanded Spitzer's original study (*11*) to include twice the number of replications and several aspects of forecast performance. We have shown that using the inverse Box-Cox

Table 6—R^2 for the estimation sample and mean bias (MB), mean absolute bias (MAB), and root mean square error (RMSE) of forecasts

λ	N	R^2[1]	MB	MAB	RMSE	Mean values: True	Mean values: Forecast	Error[2]
	Sample size	*Estimates*						*Percent*
−1.5	30	0.85	−0.005	0.034	0.144	0.263	0.258	2
	60	.78	.008	.039	.229	.269	.277	3
−1.0	30	.82	.013	−.062	.631	.202	.215	6
	60	.78	.052	−.163	2.198	.251	.303	17
−0.15	30	.65	.023	−.057	.585	.082	.106	23
	60	.35	.001	−.070	.628	.107	.108	< 1
1.0	30	.95	−.022	−.559	.708	24.887	24.865	< 1
	60	.95	−.051	−.550	.693	24.898	24.847	< 1
1.5	30	.95	−.006	−.168	.213	11.051	11.045	< 1
	60	.95	−.016	−.166	.209	11.054	11.039	< 1

[1] R^2 is measured in terms of the original untransformed dependent variable.
[2] Percentage error is calculated as $|MB|$ /mean × 100%.

transform to forecast Y from Y(λ) leads to a biased estimator. We used a second-order Taylor series expansion to approximate the expected value of the original (untransformed) dependent variable. The size of the forecast bias depends on the size of the equation error variance and on the degree of nonlinearity in the model as measured by the departure of λ from 1.0.

The properties of the parameter estimators in this study are consistent with those found by Spitzer and support his pioneering research in this area. However, based on our larger number of replications, we were able to detect an emerging pattern of bias in the estimator of the equation error variance, which was neither obvious nor reported in Spitzer's study (*11*).

Parameter bias was not a significant problem in the models with $\lambda < 0$, but there was evidence of bias in models with $\lambda > 0$. It was fortunate that the MB in parameters showing the largest MB's dropped markedly when sample size was increased from 30 to 60 observations because one can have greater confidence in the parameter estimates as samples increase.

The RMSE's and the MASD's of the parameters indicated that parameter estimators in models with negative λ had tighter sampling distributions than those in models with positive λ. The results also showed that the distributions narrowed considerably as the sample size increased. The closeness between the RMSE's and the MASD's suggests that variance estimates for the parameters obtained from the inverse of the convariance matrix of the gradient of the likelihood function were good estimators. Spitzer found similar results for variance estimates obtained from the Hessian matrix using Newton's method.

In contrast to the parameter estimators, models with $\lambda > 0$ appeared to forecast remarkably well. The reason models with positive λ's yield poorer parameter estimates but better forecasts than models with negative λ's is unclear, but it seems to be related to the relative variances of the original and transformed dependent variable and to the distribution of the untransformed equation error. By construction, all models had the same variance for the transformed dependent variable. However, the untransformed variable had a larger variance as λ approached 1.0. Further research on this point may provide some useful guidelines for the applied researcher when applying the Box-Cox transformation to variables with particular distributions.

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Appendix: Data Generation and Estimation

Some 100 successive data samples were generated for each model and sample size specification in the Monte Carlo study by use of a procedure set forth by Spitzer (*11*). Each generated data sample was divided into two subsamples: one used for estimation and the other for forecast evaluation. Without loss of generality, the first N observations were placed in the estimation sample and the remaining K observations were placed in the forecast sample, where N = (30, 60) denotes the estimation sample size and K = 10 denotes the forecast sample size.

The transformed independent variables were obtained as follows: first, N + K pairs of uniform pseudorandom numbers (W_{1t}, W_{2t}) were generated by use of the Lehmer multiplicative congruential method from the LLRANDOM II computer package (*9*). This generator has the form:

$$U_{n+1} = A \cdot U_n \ (\text{modulo } 2^{31} - 1)$$

where A = 397204092. When this value of A is used, the generator has very good statistical properties. A starting seed value for the process was specified as $U_0 = 4312657$.

Next, the N + K pairs were forced to orthogonality and standardized to zero mean and unit variance. The transformed independent variables $X_1(\lambda)$ and $X_2(\lambda)$ were obtained from the W_i as:

$$X_{1t}(\lambda) = 5 + (3)^{1/2} W_{1t},$$

$$X_{2t}(\lambda) = 45 + (0.4)(27)^{1/2} W_{1t}$$

$$+ [(0.84)(27)^{1/2}] W_{2t}, \ t = 1, 2, \ldots, N + K$$

For negative λ, each $X_{it}(\lambda)$ was multiplied by −1.0 to ensure that X_{it} was in the positive domain as required by the Box-Cox transformation. This specification implies a correlation between $X_1(\lambda)$ and $X_2(\lambda)$ of 0.4. The inverse Box-Cox transformation was applied to the $X_i(\lambda)$ to obtain X_1 and X_2.

We obtain the Y_t by untransforming the $Y_t(\lambda)$ computed from:

$$Y_t(\lambda) = 9.0 - 1.5 X_{1t}(\lambda) + 0.5 X_{2t}(\lambda) + \epsilon_t$$

where ϵ_t is an independently, identically distributed normal random error term generated with mean zero and variance 0.426. If $Y_t(\lambda)$ fell outside the feasible range such that the untransformed Y_t could not be computed, then another error term was generated to compute a replacement. This situation occurred only infrequently, suggesting that truncation of the error term (deviation from the assumption of normality) was not a significant problem for the specified models.

Marsaglia's "rectangular-wedge-tail" procedure as implemented in LLRANDOM-II was used to generate the pseudorandom normal error term. The error variance, σ^2, was chosen to make the residual variance approximately 5 percent of the total variance of Y(λ).

Research Review

A Note on Explaining Farmland Price Changes in the Seventies and Eighties

Luther Tweeten

Farm real estate values from 1981 to 1985 fell by percentages unprecedented since the Great Depression (table 1). Nominal land values fell 47 percent in Iowa and an average of 17 percent in the contiguous 48 States. Adjusted for 25-percent inflation (as measured by the gross national product implicit deflator), real land values in the Corn Belt as of April 1, 1985, had fallen to less than half their real value as of February 1, 1981. The U.S. nominal capital loss was $154 billion from 1981 to 1985.

The popular press and some economists contended that plungers and speculators dominated the land market of the seventies, raising land prices to levels unjustified by agricultural earnings and ensuring collapse. The farmland market may indeed by characterized as "collapse" in many States. At issue is whether land prices fell in the eighties because farm real estate in the seventies was overpriced relative to the prospective earning capabilities of land in agriculture. Or did land prices collapse because of fundamental changes in underlying conditions that even prudent investors could not have foreseen and avoided? The basic issue is whether the land market is efficient, using available information to price land according to rational expectations of prospective future earnings of the land. I contend that the farm real estate market is reasonably efficient and that land was not overpriced in the seventies based on prudent expectations at the time.

Table 1—Farm real estate value per acre and total value, selected years

State	Farm real estate value per acre: Feb. 1, 1981	April 15, 1985	Change, 1981-85	Change, 1973-81	Total value of farmland and buildings: Feb. 1, 1981	April 1, 1985	Change, 1981-85
	Dollars	*Dollars*	*Percent*	*Percent*	*Million dollars*	*Million dollars*	*Million dollars*
Michigan	1,289	1,052	−18	171	14,695	11,990	−2,705
Wisconsin	1,152	847	−26	220	21,427	15,254	−6,173
Minnesota	1,281	823	−36	359	38,942	25,032	−13,910
Ohio	1,831	1,126	−38	264	29,479	17,794	−11,685
Indiana	2,031	1,259	−38	293	34,121	20,651	−13,470
Illinois	2,188	1,314	−40	289	63,014	37,717	−25,297
Iowa	1,999	1,064	−47	317	67,366	35,754	−31,612
Missouri	990	659	−33	195	30,987	20,433	−10,554
North Dakota	436	360	−17	254	18,007	14,759	−3,248
South Dakota	329	250	−24	233	14,706	11,116	−3,590
Kentucky	1,033	906	−12	178	15,082	13,142	−1,940
Tennessee	1,070	962	−8	143	14,445	13,156	−1,289
Georgia	971	865	−11	124	14,080	11,676	−2,404
Alabama	910	769	−15	188	10,829	8,844	−1,985
Arkansas	1,056	849	−20	194	17,213	13,671	−3,542
Oklahoma	681	566	−17	169	23,154	18,684	−4,470
48 States	819	679	−17	198	843,657	689,807	−153,850

Source: (*5*). Italicized numbers in parentheses refer to items in the References at the end of this note.

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Conceptual Framework

In a well-functioning land market, the land price would be expected to equal discounted future earnings from land. Land market participants offering less than this price would have land bid away from them by buyers content with a lower rate of return, and rational buyers would not pay more for land because their capital would earn more if invested elsewhere.

A simple formula for the current price of farmland is (*4*)[1]:

$$P_t = R_t/(b-i') \qquad (1)$$

or rearranging terms:

$$(R_t/P_t) = b-i' \qquad (2)$$

where P_t is land price per acre in year t, R_t is land earnings or rent in year t, b is the desired or equilibrium market real rate of return on investment in farmland, and i′ is the expected real annual increase in land earnings. The latter assumes that land market participants view future real land earnings as a constant percentage trend that may be positive, zero, or negative. Evidence of speculation is present if the actual land price exceeds the present value of land, P_t, computed from equation (1) based on reasonable expectations for future earnings and the desired rate of return.

Explaining Land Prices at the End of the Seventies

As noted in equation 2, the ratio of land prices to land earnings is expected to equal $b-i'$, where b is the desired rate of return (which is influenced by the real farm mortgage interest rate and expected returns on alternative investment opportunities) and i′ is the expected trend in real land earnings. Each parameter is influenced by past values.

Expectations for Real Earnings from Land

First, consider what would be a realistic expectation in 1980 for i′, the future rate of increase in real earnings from land in agricultural uses alone. A start is to examine a realistic expectation of future aggregate supply-demand balance and real farm prices for the eighties. The U.S. population grew just over 1 percent annually in the seventies and could be expected to grow at least 0.9 percent annually in the eighties. Per-capita real disposable income grew 1.8 percent per year in the seventies and, as of 1980, could be expected to continue to grow at that rate. In real terms, U.S. farm exports grew 10 percent annually in the seventies, and it seemed realistic to expect real exports to increase 3 percent per year in the eighties. Farm exports were 30 percent of farm output in 1980. Given the above parameters and assuming a 0.1 domestic income elasticity of demand, the expected rate of increase in total demand for farm output was 1.66 percent annually.

One must compare this expected growth in demand with expected growth in supply due to productivity gains to determine expected trends in real commodity prices. Productivity measures vary widely from year to year (due to weather), making forecasts difficult. After growing at 2.4 percent per year in the fifties, multifactor productivity growth slowed to 1.2 percent per year in the sixties and 1.5 percent per year in the seventies. It was surely not imprudent for investors to anticipate that productivity growth would not exceed expected growth in demand of 1.66 percent annually in the eighties so that real farm prices and income would be maintained.

Table 2 shows real net rent (gross cash rent less property taxes adjusted by the GNP implicit deflator) trends for 16 States, States for which data are most reliable and coincidentally including States for which land prices fell the most in 1980-85.[2] Real land rents increased in all 16 States in the seventies and declined significantly in only one State, Michigan, in the sixties. If investors desired a real rate of return, b, of 4 percent on farmland from agricultural earnings alone in the eighties, then, if one applies equation 2, such a real return would be forthcoming even if real net returns fell in 10 States (as noted in the last column of

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[1] Italicized numbers in parentheses refer to items in the References at the end of this note.

[2] Land cash rents are a contractual obligation that reflect expectations of earnings, but that would not be expected to reflect speculative expectations about land price. Although cash rents are not a perfect measure of land earnings, Pongtanakorn found they predict land price changes much more accurately than does net farm income. Land earnings were increasing in the seventies, and cash rents tended to lag trends in real land earnings. Hence, cash rents might have been expected to underestimate expected real land earnings in 1980.

Table 2—Actual real rate of increase in net cash land rent, 1960-69 and 1970-79, and expected future rate of increase based on 1980 conditions

State	Annual rate of increase, i′, in real net cash rent		
	Actual average		Expected if b = 0.04 or 4 percent
	1960-69	1970-79	1980[1]
	Percent		
Michigan	−1.83	4.32	1.23
Wisconsin	.26	2.18	.31
Minnesota	1.80	4.61	−.49
Ohio	1.72	6.94	.48
Indiana	1.85	6.20	−.49
Illinois	2.98	4.39	.25
Iowa	3.77	5.39	−.18
Missouri	3.61	4.95	−1.49
North Dakota	4.16	5.38	−1.53
South Dakota	2.67	1.73	−.90
Kentucky	.38	2.11	−.60
Tennessee	−.12	.69	−.46
Georgia	2.02	.09	.18
Alabama	1.45	.98	−.72
Arkansas	.26	2.72	−.91
Oklahoma	2.69	2.29	1.10

[1] Computed from formula $i' = b - (R_t/P_t)$, where b is the desired real rate of return on farmland investment, R_t is the current net land rent, and P_t is the current land price.

Source: Unpublished worksheets, Economic Research Service, U.S. Department of Agriculture. Net rent is gross cash rent less property taxes.

table 2). In States where real rents were expected to increase under these assumptions, the increases tended to be small relative to those in the seventies. These results suggest that investors were being cautious in 1980.

Expectations for the Discount Rate

Using econometric techniques and several alternative formulations including Almon-distributed lags to estimate equation 2, Pongtanakorn was unable to reject the hypothesis that land market participants view i′ as zero (*3*). Hence, it is useful to turn our attention to the second major parameter, b, which determines land value and the land rent-price ratio. The expected value of b, the real rate of return on farmland, may be influenced by the real farm mortgage interest rate and the expected return on alternative opportunities.

The real farm mortgage interest rate averaged 2-3 percent in the sixties, a rate characteristic of earlier decades as well (table 3). Real interest rates averaged near zero in the seventies and were negative in 1980. If i′ is zero and if land investors had used the real rate of interest in the seventies as their desired real rate of return on land investment, b, they would have paid a nearly infinite price for land in 1980.

Investors desired a real rate of return on land greater than real farm mortgage interest rates in the seventies. If i′ is zero, the ratio of net rent to land price indicates the real rate of return expected by investors in the land market. Table 3 shows that rate by actual ratios for the sixties, seventies, and 1980. The ratio in 1980 averaged 4.3 percent for the 16 States. Oil and natural gas earnings probably accounted for the low ratio in Oklahoma. The relatively low ratios (below 4.0) in Michigan, Wisconsin, Ohio, Illinois, and Georgia can be partly explained by urban influences that Pongtanakorn found to be statistically significant in reducing rent-land price ratios. When these States are omitted, the average rent-land price ratio, as a measure of expected real land returns, was 4.8 percent. Thus, if real interest rates had remained at historic levels of 2-3 percent and if real land earnings had remained constant in the early eighties, land investors would have realized real earnings approximately double real interest rates.

It is impossible to know the desired or equilibrium real return on farmland relative to the real rate of interest, but the return on farmland in 1980 was more than adequate to cover historic farm mortgage rates and far in excess of that rate in 1980. Furthermore, expected real rates of return on farmland in 1980 as measured by rent-value ratios were well in excess of rates of return on major alternative investments. Total rates of return on common stock and long-term bonds averaged negative in the seventies (*7*). Again, no evidence points to a land market in 1970-80 dominated by speculators and plungers who paid more for land than its present value based on reasonable expectations of future earnings in agriculture alone and expected future real interest rates.

Table 3—Ratio of net cash rent to farmland value and real farm mortgage interest rate, selected years

State	Real farm mortgage interest rate			Ratio of net cash rent to land value			
	Actual			Actual			Predicted
	1960-69	1970-79	1980	1960-69	1970-79	1980	1980
	Percent						
Michigan	2.42	−0.03	−1.0	4.77	3.60	2.77	2.80
Wisconsin	2.42	−.03	−1.0	6.48	4.99	3.69	3.92
Minnesota	2.42	−.03	−1.0	6.25	5.99	4.49	4.95
Ohio	2.67	.08	−1.1	5.60	4.18	3.52	3.82
Indiana	2.67	.08	−1.1	5.85	5.74	4.49	5.13
Illinois	2.67	.08	−1.1	4.61	4.56	3.75	4.02
Iowa	2.67	.08	−1.1	5.43	5.71	4.18	4.49
Missouri	2.67	.08	−1.1	6.15	5.88	5.49	5.56
North Dakota	2.59	−.06	−1.3	7.53	6.96	5.53	5.90
South Dakota	2.59	−.06	−1.3	6.25	5.90	4.90	5.36
Kentucky	3.01	.47	−.8	7.36	5.83	4.60	4.66
Tennessee	3.01	.47	−.8	8.74	5.56	4.46	4.41
Georgia	3.25	.65	−.6	9.29	4.93	3.82	3.81
Alabama	3.25	.65	−.6	8.94	5.68	4.72	4.76
Arkansas	3.18	.37	−1.0	7.52	5.65	4.91	4.11
Oklahoma	2.77	.08	−1.4	4.27	3.77	2.90	3.23

Source: Unpublished worksheets, Economic Research Service, U.S. Department of Agriculture. Predicted rent-value ratio from (*3*).

The Predicted Rent-Value Ratio

The ratio of net rent to land value decreased from the sixties to 1980. It is useful for us to pursue further the issue of whether land was overpriced in 1980 relative to earning capabilities after accounting for factors influencing land prices not explicitly dealt with in the foregoing analysis.

Pongtanakorn used regression analysis to explain the change in the ratio among 35 States from 1962 to 1982. The ratio was significantly influenced by population density (urbanization raised the value of farmland relative to rent), by the share of Federal Land Banks in real estate lending (interest rates were lower historically on such loans than on alternative sources of mortgages, hence raising land values relative to rent), by the real rate of interest, and by a time trend. The inflation rate and the past trend in real rents (a measure of i′) did not significantly influence the rent-price ratio[3]. Inflation could have had an indirect impact on the time trend, which indicated an $18-per-year increase in land prices in the 35 States included in the model.

Inflation could have also influenced the real mortgage interest rate, which declined because inflation was unanticipated and added to land price. The inflation rate significantly lowered the rent-price ratio through interaction with the tax rate, an expected result because high inflation rates would be expected to raise the value of land relative to other investments. Capital gains were taxed at a lower rate than ordinary income. Therefore, income from land, which has had a large capital gain component, has been taxed at a lower rate than income from bonds and other investments with a lower capital gain component.

Predicted land rent-price ratios from Pongtanakorn exceeding actual values in 1980 could be interpreted as evidence of speculation in land markets. In the Corn Belt where land values have fallen most since 1980, predicted ratios exceeded actual ratios. The actual ratio exceeded the predicted normal ratio in Iowa by 7 percent, indicating that land values would need to fall 7 percent to restore the "normal" ratio if net rents remained constant. Differences in other States also were small and did not suggest that nominal land rent-price ratios were far out of line with the historic structure of land markets. The close fit of actual-to-predicted rent-price ratios again provides no evidence that speculation played a major role in the land market in the seventies.

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[3] See (*1*) for recent estimates regarding inflation.

Explaining Sources of Falling Land Prices in the Eighties

If speculation cannot be blamed for land market behavior in the seventies, it follows that bursting a speculative bubble cannot explain the sharp drop in land prices after 1980. What went wrong to so rudely contradict seemingly rational expectations for land prices in 1980? Again, land earnings and discount rates give clues. Gross farm income, net farm income, cash flow, and land rents held up well from 1980 through 1984 and hence cannot be blamed for falling land prices in that period (*2*, *6*).

We must look to the discount rate to explain the large decrease in land prices. The real interest rate on Federal Land Bank mortgages went from negative in 1980 and 2.4 percent in 1981 to approximately 8-9 percent from 1982 through 1985. These latter rates were at least triple historic levels, excluding the seventies when rates were abnormally low. Potential land buyers who faced payments of such rates could hardly ignore them when judging how much to pay for land. It is apparent from equation 1 that the tripling real interest rates alone could sufficiently change discount rates to justify the fall in land values to half their 1980 level.

Falling land rents in 1985 further depressed farmland values. If the structure of land price determination has changed so that expectations of falling real land earnings enter the formula in equation 1, the expectation of a negative i' would likely depress land values further. Declining exports, excess capacity reflected in diverted acres and large commodity stocks, efforts to reduce budget deficits including farm program spending, and uncertainty over new farm commodity legislation provide little basis for optimism for real land earnings to increase in the near future. Thus, declining land earnings could continue to depress land values, even if real interest rates continued to fall.

Conclusions

The farmland market is reasonably efficient. It responds to available information, pricing farmland relative to its present value based on real interest rates and earnings from land in agricultural uses, the latter measured by cash rents in this study. In 1980, farmland was not overpriced relative to reasonable expectations of future earnings and real interest rates. Rent-value ratios in 1980 were at levels that could provide a real rate of return more than adequate to cover normal real interest costs of previous decades in the memory of investors, even if real land earnings failed to increase. Economists and noneconomists alike were optimistic about future land earnings in 1980. Of course, some plungers and speculators bid recklessly for land, but they did not dominate the land market. Other investors were conservative so that on average it is not possible to conclude that land prices were out of line with prospective future earnings from land in agricultural use alone.

Land values fell after 1980 primarily because of direct and indirect impacts of high real interest rates. The unanticipated rise in real interest rates to unprecedented levels is attributable to several sources, but a major source is large structural (or full employment) Federal deficits. The deficits influenced both the discount rate and rent in the formula for land value in equation 1. High real interest rates not only raised the discount rate; they also reduced rents by raising the value of the dollar which, in turn, reduced farm exports. The problem was compounded by commodity program support rates, holding prices at levels that encouraged continued output and discouraged exports. The resulting commodity surpluses brought program changes in 1985 that would initially depress farm prices and land earnings. Factors such as OPEC oil price increases and expansion in U.S. and world money supply and credit in the seventies to levels bringing unsustainable inflation and debt also contributed to high real interest rates and reduced farm exports in the eighties. Commodity programs did not offset the negative input of macroeconomic policies.

Farmers and other land investors did not anticipate and could not have been expected to anticipate the tripling of real interest rates from historic levels. Imprudent decisions regarding macroeconomic policy in the past decade rather than imprudent investors in land are mainly responsible for the financial stress in agriculture today.

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In Earlier Issues

Paarlberg states that "[People] see the windfall gains that accrued to landowners during the past forty-five years. They bid up the price of land to levels not justified by its present or prospective earnings " (p. 689). I contend current land prices can be justified by prospective earnings.

Luther Tweeten
Vol. 32, No. 3, July 1980

Rivers of Empire: Water, Aridity, and the Growth of the American West

Donald Worster. New York: Pantheon Books, 1985, 402 pp., $24.95.

Reviewed by Ralph E. Heimlich

Rivers of Empire is a history, but the kind economists should read more often. It intertwines the social organization consequent to a particular form of economic development engendered by a specific ecologic regime: the arid West. Worster's thesis, presented in contemplation of a sterile, concrete-lined ditch in Kern County, CA, so different from the pond that served as Thoreau's muse, is that the social order is conditioned by natural resource constraints. While the concept should be of particular interest to resource economists, Worster points out that economists were as apt to ignore the social consequences of water resource development in the West as the engineers who designed the dams and canals.

As Worster admits, his predecessor in the study of resource determinants of social organization was Karl August Wittfogel, who wrote in post-World War II Germany and fled from the Nazis to Seattle. Wittfogel was a historical materialist influenced by Marx and the sociology of Weber. Part of the Frankfurt school of radical social thought in the twenties, Wittfogel restored the neglected ecological factor in Marxist historical materialism, emphasizing the natural environment and technology as a means of production that shaped the social order as much as, if not more than, labor and the forms of property ownership. Given Worster's earlier work on the development of ecology as a discipline, Wittfogel's theory probably struck a sympathetic chord. Focusing on ancient Egyptian, Babylonian, Indian, and Chinese societies, Wittfogel postulated a synergism between the development of complex irrigation systems and the rise of centralized, despotic social organizations needed to control them.

Worster extends Wittfogel's taxonomy of hydraulic societies to encompass water resource development in the modern world. (Wittfogel, in a curious lapse, became an apologist for irrigation development in his adopted American West.) Wittfogel delineated a *local subsistence mode* of irrigation technology, which depends on traditional village organization to accommodate agricultural production to natural moisture cycles in arid environments, and an *agrarian state mode*, in which a centralized, autocratic social order and a complex irrigation system develop simultaneously. In the agrarian state mode, society becomes increasingly regimented as the naturally occurring water resource comes more and more under human control, and Wittfogel thought that this development was incompatible with a preexisting democracy. Worster adds a *capitalist state mode* to Wittfogel's taxonomy in which power and wealth are concentrated and reinforced by the development of water resources necessary for intensive irrigated agriculture, even in nominally democratic societies.

Worster's capitalist state mode of hydraulic social development contrasts with other historical theories of societal development in the West. Beginning with Frederick Jackson Turner's theory of the frontier in American social development and continuing through the writing of Walter Prescott Webb, Bernard DeVoto, and the more recent proponents of the Sagebrush Rebellion, social historians have claimed that the harsh conditions of the American West called forth a rugged individualism and a democratic decentralized society long lost in the industrialized giantism of the eastern seaboard. Worster contends that the development of large-scale irrigated agriculture in the West, conditioned by scarce natural water, is more nearly akin to the rise of centralized capital in the East than to the mythic rugged, self-reliant Western pioneer spirit. Of interest to public servants are the roles of Federal capital and technical expertise in this development and the consequent power of the technical elite, including economists, to control the flow of water and wealth in the West.

The book then presents a four-part history of Western irrigation development. The chapter titled "Incipience" traces the first encounters of explorers and pioneers with the "Great American Desert" west of the Mississippi, particularly southern California. This section documents early visitors' reactions to the original landscape as the antithesis of arable land, let alone its future role as one of the world's garden spots. The efforts of early irrigation

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communities such as the Mormons in Utah, the Greeley experiment in Colorado, and the early small irrigators in Kern County are described. These localized cooperative ventures illuminated both the potential for irrigation to make the desert bloom and the limitations of local capital to support needed irrigation development.

"Floresence: The State and the Desert" describes the entry of more sophisticated hydraulic engineering schemes, building on the contemporaneous examples of British colonial projects in India and Australia. The cost of these larger works was too much for local capital and implied a planning horizon too long for existing national sources of private capital. The plateau at which irrigation development proponents found themselves by the 1890's could be surmounted only if Federal capital were made available to finance the vastly greater hydraulic potential that technical experts saw for the region. Congress acquiesced with the National Reclamation Act of 1902 which, in several manifestations over the succeeding 80 years, financed the major capital infrastructure of industrialized agriculture in the irrigated West.

"Floresence: The Grapes of Wealth" describes the third chapter in which Worster related the final conquest of natural water by the unique partnership of the technical and economic elite that came to rule not only the water but also the West. This pattern of technical dominance over nature and social dominance over other men became most highly developed in California. Worster describes the tension between the technical elite who controlled the water, mainly the Federal water management agencies, and the economic elite who controlled the land, organized and ran the giant fruit and vegetable farms, and reaped the wealth. This chapter covers the Depression era and the emergence of social critics such as John Steinbeck and Carey McWilliams, who provided an intellectual edge to early labor organization attempts among migrant fieldworkers. This period also saw the emergence of economic critics such as Marion Clawson and Walter Goldschmidt, who studied the California Central Valley project for the Bureau of Agricultural Economics, the predecessor agency of the Economic Research Service.

Finally, we arrive at the fourth chapter, "Empire," the modern hydraulic society in the postwar West. The section, "Leviathan Ailing," in this chapter is particularly interesting because it weaves together a series of seemingly disparate problems, such as salinity, sedimentation, pesticide contamination, falling ground-water levels, collapsing dams, and the "free rivers" movement, to question the continuing viability of a now mature hydraulic society. Worster concludes that the virtual freeze on new water resource development projects since the Carter administration may mean that sustaining the West's hydraulic empire is more difficult than its original construction.

Rivers of Empire has several lessons for economists, especially those who are part of the technical elite who justified and built the irrigation projects that made the West's hydraulic regime possible. First, economists and other technical experts failed to anticipate the size and dominance of industrialized irrigated agriculture because the costs of creating and sustaining such large and complex enterprises required a vastly different economic structure than the family farm of eastern, nonindustrial agriculture. The unique partnership between Federal water management agencies and the large landowners transcended the feasible limits of private agricultural firms, resulting in an agriculture whose scale and organization were completely unforeseen by agricultural economists. Second, economists have been too narrow in evaluating the success of irrigated agriculture, focusing on narrow measures of technical efficiency, such as the 160-acre limitation, and ignoring the wider institutional milieu that surrounds western irrigated agriculture and makes it work. Western industrial agriculture may offer important clues to economists concerning the eventual industrialization of the rest of U.S. agriculture.

One unsatisfactory aspect of the book is the scant attention Worster pays to reverse linkages in his materialist argument. Although most of the book argues that responding to and overcoming the water-poor environment of the West led to a particular social and economic structure, Worster only briefly touches on the impact of that structure on the West's environment. Only at the end does he hint that environmental determinism can be a two-way street with complex feedback loops further conditioning the economic and social systems that have evolved as responses to the original environment. Given Worster's earlier writing on the development of ecological thought, one could hope for more than a simple stimulus and response in his thesis regarding hydraulic societies and how they develop.

The book is impeccably written, as we should expect from a professor of history at Brandeis University, and it offers a fascinating and informative look at the agricultural development of one of the world's richest producing areas. It contains much that should literally broaden economists' minds.

In Earlier Issues

The sources of institutional and technical change are similar. Just as the supply curve for technical change shifts as a result of advances in knowledge in science and technology, the supply curve for institutional change shifts as a result of advances in knowledge in the social sciences and related professions (law, administration, social services, and planning).

Vernon W. Ruttan
Vol. 31, No. 3, July 1979

Agricultural Policies and World Markets

Alex F. McCalla and Timothy E. Josling. New York: MacMillan Publishing Company, 1985, 286 pp., $38.00.

Reviewed by H. Christine Bolling

The decade of the seventies was the era of U.S. agricultural trade. U.S. agricultural exports were the bright spot in total U.S. trade, bolstering the slipping total trade balance. While the seventies posed important policy questions—for example, the impacts of the devaluation of the dollar and high petroleum prices—the eighties have become a real challenge as we have seen agricultural markets shrink and prices plummet. Agricultural economists must now, more than ever, understand foreign markets to evaluate U.S. policy options.

McCalla and Josling provide the tools for the job; they have written a timeless book as well as a book for the times. They focus on the important policy choices facing agricultural policymakers around the world. They go beyond the neoclassical free trade case to the complexities of import levies, quotas, and other governmental policy instruments. They also present illustrations of the impacts of policy instruments in both the small-country and large-country cases, and macroeconomic linkages within and among countries. The graphics are especially helpful in explaining the effects of changes in exchange rates on wheat and cotton markets.

Two chapters deserve special mention. "Interdependence in Practice" provides an excellent description of how the analytical tools presented earlier relate to real world cases. The wheat market of the seventies is a well-chosen case study. Wheat is the most important agricultural commodity in terms of its value in international trade and is subject to more government intervention than nearly any other commodity. Consequently, it has probably been subjected to more study by agricultural economists than any other commodity. But McCalla and Josling do more than just repeat other people's work. Their analysis is a concise explanation of the factors that came together to cause the price explosion in the international wheat market in 1972-74, including the shortfall in the world wheat crop, the change in the Soviet grain importing policy, and the realignments in the international economy that were reflected in changes in exchange rates.

Another section of this chapter deals with the Common Agricultural Policy (CAP) of the European Community (EC), a classic case of government intervention in agriculture. The analysis of EC agricultural policy, one of Josling's specialties, is similarly excellent. The subchapter called "The Cassava and Corn Gluten Caper" emphasizes how government intervention in one market can effectively alter world trade patterns of other commodities over time. The authors focus on why the EC was once a large importer of U.S. wheat and corn (commodities most affected by the CAP), but is no longer. Corn gluten meal and cassava chips were not even imported 20 years ago, but, because they were exempt from the exorbitant variable levies applied to grains, they have now become large livestock feed import items.

Chapter 8, "National Policy Choice in Practice," provides another excellent demonstration of the authors' skill in analyzing real world policy issues. Much of this chapter was from earlier work prepared for a University of California-Government of Egypt project funded by the U.S. Agency for International Development. The authors focus on tradeoffs among the Egyptian wheat, cotton, and beef programs, identifying the costs and benefits in terms of foreign exchange and domestic government expenditures, to determine how much of these basic products should be produced domestically and how much should be imported commercially. To develop these tradeoff functions, the authors change the relationships between the support price and the world price and are thereby able to trace out a tradeoff frontier. This thoughtful approach allows them to analyze the myriad cross-effects among commodity-specific programs. This section also shows how policy decisions in the farm sector affect the macroeconomy and vice versa.

Other case studies of general interest are the U.S. PIK (payment-in-kind) program and the international dairy market. By the end of their economic analysis, McCalla and Josling have brought us "both closer to the real world of choices and further away from neat simple policy analysis" (p. 163) very successfully. The latter chapters deal with

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international organizations and global policy goals, the role of stability, food aid, and other policy issues.

There are a few parts that I would have done differently. The authors do not mention explicitly all the main players in the international wheat and cotton markets. For example, China, Korea, Japan, Brazil, and sometimes India are important wheat importers, and Australia is one of the top four wheat exporters. Although their roles are less dramatic than those of the countries highlighted here, they are not mentioned. The same thing is true for the cotton market. The USSR is the second largest cotton exporter. China is the present destabilizer of the cotton market. Korea and Thailand are also some of the main players on the import side, but they are not mentioned. I would have opted for a graph of all the major traders, possibly extending the otherwise very informative graph on the impacts of an appreciation of the U.S. dollar on the wheat and cotton markets on page 89 into two graphs. In another vein, the mathematical economists among us may miss a mathematical presentation of the material (possibly as an appendix). The authors have demonstrated their skills in this area in other publications.

McCalla and Josling have given us a tool to analyze the continuing developments in international agricultural trade more intelligently. Their book is thoughtful and sophisticated. It is a pleasure to read a book of its caliber pertaining primarily to agricultural trade policy, while also incorporating the issues of the larger world.

In Earlier Issues

If confined to a single-product partial equilibrium framework, analysis of changes in commodity policies will yield erroneous estimates of the magnitude of their impacts when products are interrelated. It is also possible that using a single-product partial equilibrium model may result in errors in predicting the direction of changes in endogenous variables with respect to policy changes. The final result is an important empirical issue which can affect policy recommendation.

Philip L. Paarlberg and Robert L. Thompson
Vol. 32, No. 4, October 1980

The Organization and Performance of the U.S. Food System

Bruce W. Marion, NC 117 Committee, Lexington, MA:
Lexington Books, 1986, 532 pp., $39.00.

Reviewed by Howard C. Madsen

This book summarizes the research of NC 117 (North Central Regional Research Project 117), which became an institutional entity in 1973. It was formed to describe, diagnose, and prescribe changes in the organization of food production and marketing in the United States.

This book does more than summarize research findings. Providing a wealth of information on several agricultural subsectors (food production, manufacturing, and distribution), the book is an excellent reference for economists, analysts, and researchers. If aimed at policymakers and managers, however, it falls short.

The book has five parts with different authors and coauthors for each part. To its credit, the book pulls together a considerable amount of research on the U.S. food system. It lays out issues relative to agricultural production, food system coordination, food manufacturing and distribution, the legal environment of the U.S. food system, and policy options. The authors list what they call six highly visible issues: (1) the farm financial crisis, (2) the ability of the United States to compete in world commodity markets, (3) the number and size of food company mergers, (4) the Government push for deregulation, (5) turmoil in the labor markets, and (6) the national debt.

The authors have attempted to identify the driving variables of the U.S. food system. What is not clear is how they rank those variables from the most to the least important. For example, the authors mention tax structure and policy as a major factor. But as to whether it's a first-ranked major factor or a 20th-ranked major factor, the authors are silent. Nor do they attempt to forecast where all these factors will lead us if they were to continue unabated. Had they done so, one might then be able to work backwards and identify the best candidates for change. This type of forecasting would make the research more useful for policymakers and managers.

The authors treat general economic factors more qualitatively than quantitatively. They barely mention the effect of environmental concerns on the U.S. food system. In the final chapter, the authors pose 10 policy issues for public action, such as goals of the farm program in the eighties, food quality issues, advertising, and conglomerates. These issues are the ones which the authors believe could be acted upon to improve food system performance. But it is not clear which ones should be acted upon first. For example, advertising is mentioned several times throughout the book. According to the authors, research results of NC 117 "indicate that tacit or explicit collusion and/or leading firm price leadership in industries with high entry barriers results in supracompetitive profits and prices in some food manufacturing industries" (p. 433). This issue is likely a controversial one, and I would like to see similar statements in the book developed further into actions. In brief, the book does not tell us what we should do next relative to the issues it raises. In fact, in trying to deal with the entire food marketing system, the book contains so much information that it is nearly impossible to digest everything in one reading. Sorting out the candidates for change involves further analysis of the research results and value judgments. This process calls for either a very long or a short review. I have chosen the latter.

Several megatrends are at work in the U.S. food system that provide a fertile ground for further research. The book is loaded with information, but further efforts analyzing what it all means would be helpful.

The reviewer is executive vice president of Agri-Commodities, Inc., a consulting and research firm in Andover, MA.

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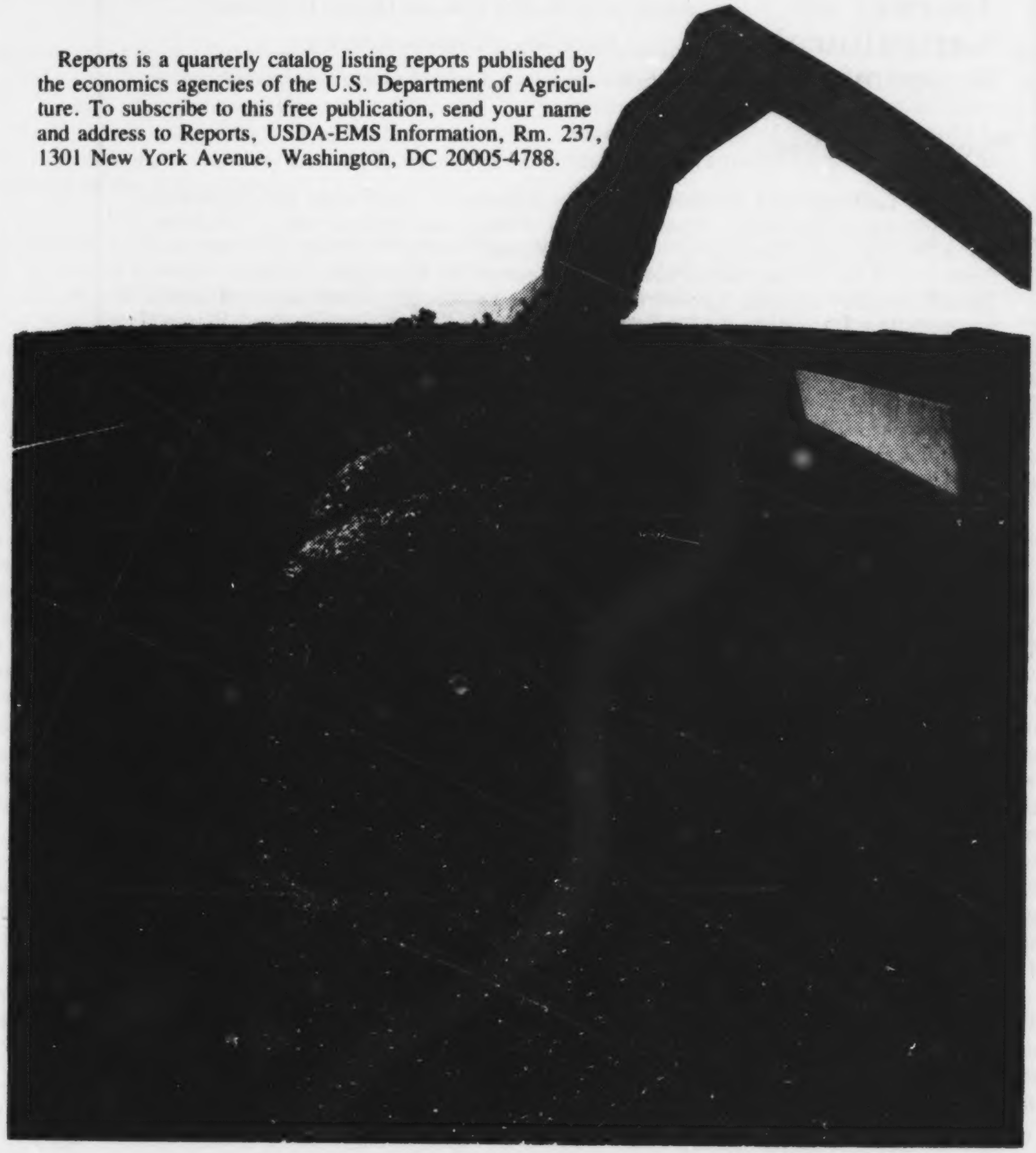

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